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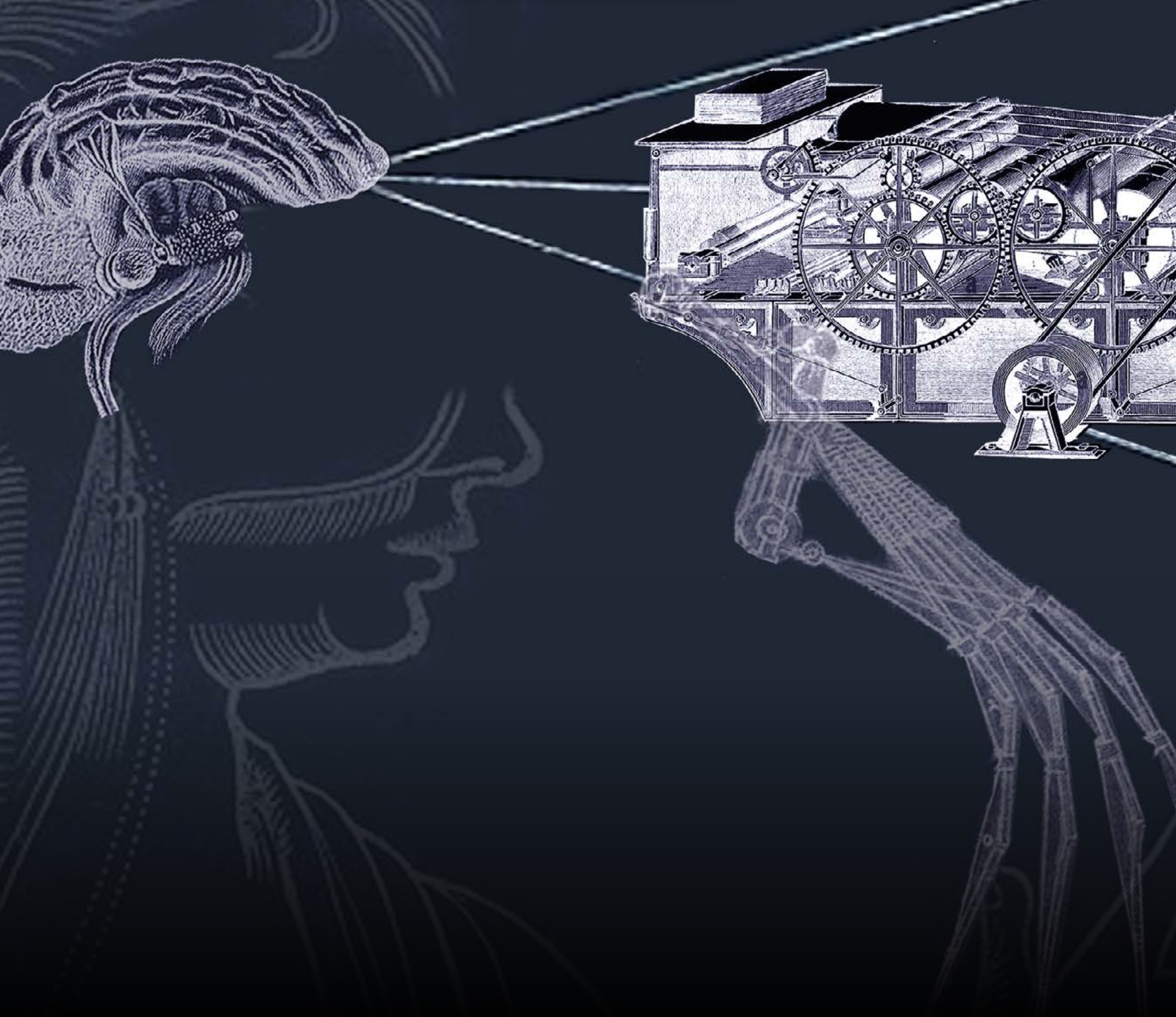

L'economia della conoscenza: innovazione, produttività e crescita economica nei secoli XIII-XVIII

The knowledge economy: innovation, productivity and economic growth, 13th to 18th century

edited by

Giampiero Nigro

FIRENZE
UNIVERSITY
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– 3 –

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2023

L'economia della conoscenza: innovazione, produttività e crescita economica nei secoli XIII-XVIII / The knowledge economy: innovation, productivity and economic growth,13th to 18th century / edited by Giampiero Nigro. – Firenze : Firenze University Press, 2023.

(Datini Studies in Economic History ; 3)

https://books.fupress.com/isbn/9791221500929

ISBN 979-12-215-0091-2 (Print)
ISBN 979-12-215-0092-9 (PDF)
ISBN 979-12-215-0093-6 (XML)
DOI 10.36253/979-12-215-0092-9

Graphic design: Alberto Pizarro Fernández, Lettera Meccanica SRLs
Front cover image: poster of the LIII Settimana di Studi/Study Week, by Letizia Finocchiaro

La Settimana di Studi è stata realizzata con il contributo di:
Ministero dei beni e delle attività culturali e del turismo

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MINISTERO DELLA CULTURA

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Published by Firenze University Press
Firenze University Press
Università degli Studi di Firenze
via Cittadella, 7, 50144 Firenze, Italy
www.fupress.com

This book is printed on acid-free paper
Printed in Italy

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Giampiero Nigro (edited by), *L'economia della conoscenza: innovazione, produttività e crescita economica nei secoli XIII-XVIII / The knowledge economy: innovation, productivity and economic growth, 13th to 18th century*, © 2023 Author(s), CC BY 4.0, published by Firenze University Press, ISBN 979-12-215-0092-9, DOI 10.36253/979-12-215-0092-9

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Erik Aerts

Le radici storiche dell'economia della conoscenza

Signor assessore, cari colleghi, studenti e amici della Fondazione Datini,

Il tema centrale della Settimana di quest'anno è la conoscenza e il modo in cui essa sia stata capace di stimolare la crescita economica ed avere un impatto sul benessere sociale nei secoli passati attraverso l'innovazione. Credo di non dovervi convincere dell'importanza sociale e dell'alto grado di attualità di questo tema. Gli esempi sono facili da trovare.

Gli attuali conflitti tra le grandi potenze politiche, chiamati anche Seconda Guerra Fredda, non sono combattuti, come nella Prima, solamente su orribili campi di battaglia o nel mondo del commercio internazionale, ma anche in quelli della tecnologia, dell'informazione e della conoscenza. Nell'attuale sistema capitalistico, l'obiettivo degli investimenti non è più costituito dalla proprietà terriera, dalle materie prime, dal lavoro e dai beni capitali, ma dallo scambio di informazioni e le reti di conoscenza (Burton-Jones 1999). I grandi mercanti internazionali, i capitani d'industria e i direttori finanziari sono stati sostituiti dai data manager e dagli specialisti dell'informazione. Le persone più ricche del pianeta come Jeff Bezos, Bill Gates, Elon Musk e Mark Zuckerberg hanno costruito le loro immense fortune tramite software, e-commerce, piattaforme di pagamento e social media incentrati sull'informazione e sulla comunicazione, basata sulla trasmissione di conoscenza. Un profeta di sventura come il filosofo, storico e futurologo Harari ha persino predetto che i grandi sistemi di trattamento dati, l'intelligenza artificiale e gli algoritmi di conoscenza creeranno una nuova elite di superuomini biologici. Grazie ai continui miglioramenti genetici, questi avranno più conoscenza e saranno più intelligenti delle masse (Harari 2016).

Già nel 1982 John Naisbitt (1982, 24) predisse l'economia dell'informazione post-industriale, ma coniò anche l'immortale frase «siamo sommersi dalle informazioni ma disperatamente affamati di conoscenza». Forse l'argomentazione più convincente per illustrare l'importanza fondamentale della conoscenza nella società attuale è il fatto che abbiamo bisogno di moltissima conoscenza per essere in grado di affrontare l'enorme flusso di informazioni[1]. Negli ultimi decenni, il mercato è stato così invaso da fake news e da ogni sorta di teoria del complotto, che molte persone hanno addirittura sviluppato una «resistenza alla conoscenza» o resistenza al «sapere costituito» (Wilkforss 2017). La maggior parte della popolazione nelle nazioni occidentali (dagli insegnanti e dai giornalisti ai dipendenti pubblici e agli avvo-

[1] Per la delicata distinzione tra informazione e conoscenza, si veda Denzel 2020, 21.

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Referee List (DOI 10.36253/fup_referee_list)
FUP Best Practice in Scholarly Publishing (DOI 10.36253/fup_best_practice)

Erik Aerts, *Le radici storiche dell'economia della conoscenza*, © Author(s), CC BY 4.0, DOI 10.36253/979-12-215-0092-9.02, in Giampiero Nigro (edited by), *L'economia della conoscenza: innovazione, produttività e crescita economica nei secoli XIII-XVIII / The knowledge economy: innovation, productivity and economic growth,13th to 18th century*, pp. 1-4, 2023, published by Firenze University Press, ISBN 979-12-215-0092-9, DOI 10.36253/979-12-215-0092-9

cati, ai bibliotecari e ai programmatori) è impegnata a creare, coordinare, trasferire e disseminare informazione e conoscenza.

Mentre è generalmente accettato che nell'economia moderna, «la principale fonte di crescita non è più il capitale fisico, ma (…) la trasmissione o lo scambio della conoscenza» (De Meyer, Gailly 2021, 5) e «che la conoscenza utile è al centro della crescita economica» (Mokyr 2002b, 25), gli storici hanno atteso a lungo prima di dare al concetto di conoscenza un posto importante nei loro modelli esplicativi. Ciò potrebbe sembrare strano dal momento che già nel Secolo dei Lumi gli intellettuali erano convinti dello stretto legame tra diffusione della conoscenza in ampi settori della popolazione e prosperità o persino felicità all'interno della società[2]. Il primo studioso moderno ad usare «conoscenza» come una variabile determinante fu lo storico economico Americano Joel Mokyr. Vent'anni fa spiegò le origini storiche dell'attuale economia della conoscenza introducendo due tipi di conoscenza: proposizionale, o teoretica, e prescrittiva, o tecnica. In parole povere, la conoscenza proposizionale riguarda il «cosa» e il «perché», mentre la conoscenza prescrittiva riguarda il «come». Analizzando magistralmente entrambe le tipologie Mokyr (2002a, 4) ha spiegato il ruolo della «conoscenza utile» nel generare crescita economica. La sua tesi centrale è che una fruttuosa interazione tra i due tipi di conoscenza, o un felice matrimonio tra scienza e tecnologia, abbia avuto luogo solo dopo il 1800, aprendo così la strada alla Rivoluzione Industriale.

Gli storici dopo di lui hanno accolto e lodato, ma anche sfidato e ampliato le sue idee. Recentemente Paul Dover (2021) ha scoperto dei cambiamenti profondi nella creazione, preservazione, circolazione e interpretazione dell'informazione nell'Europa della prima Età Moderna. Egli non ha esitato ad usare l'espressione «rivoluzione dell'informazione», che condizionò profondamente il commercio, la finanza, la scienza, la comunicazione, gli affari di stato e la politica. Altri studiosi come Leemans e Goldgar (2020) hanno dimostrato come i mercati della conoscenza non operassero solo a livello economico, ma anche culturale attraverso la comunicazione e la persuasione. Essi sostengono che l'economia della conoscenza sia anche altamente «affettiva», introducendo nel dibattito il ruolo di emozioni come speranza, ambizione, desiderio, amore, affetto, fascino, avventura, passione e lussuria. Queste discussioni e coinvolgenti scambi di idee suggeriscono chiaramente che il tema dell'economia della conoscenza meriti assolutamente una Settimana adeguata.

I contributi presentati in questa Settimana cercheranno di fornire risposte a una serie di domande intriganti. Ad esempio, attraverso quali «agenti di cambiamento» o personalità chiave e quali istituzioni, la «conoscenza utile» sia stata trasmessa tra gli individui e le comunità attraverso il tempo e lo spazio[3]. Sappiamo già che la conoscenza non ebbe in alcun modo uno sviluppo lineare, uniforme o regolare. In alcuni luoghi e situazioni, la sua circolazione fu più intensa che altrove. Quindi, quali fat-

[2] Per esempio nella Repubblica Olandese nel 1798 (Fritschy 1988, 99).

[3] Le istituzioni sono qui definite in modo molto ampio come un insieme di atteggiamenti e griglie di azione sociale, quindi secondo una definizione molto più generale che include reti, organizzazioni e sistemi (su questo si vedano le stimolanti righe di Melville 1992, 2 e Wyman 2021, 13-6). Per la nozione di agenti del cambiamento nella diffusione della conoscenza: Jones 2008.

tori furono responsabili di questa accelerazione o rallentamento del processo di diffusione? Quali istituzioni o meccanismi in particolare favorirono una situazione che permise «alla conoscenza di essere distribuita e condivisa, e quindi contestata, corretta e completata»? (Mokyr 2017, 340). Gli studiosi non solo ricostruiranno questi cosiddetti percorsi di trasmissione (Hilaire-Pérez, Verna 2006, 542), ma esamineranno anche quando, dove e in quali settori dell'economia, la massa critica o «stock» di conoscenza utile fu abbastanza sostanziale da stimolare un gran numero di innovazioni e invenzioni che contribuirono alla crescita economica (Blockmans 2021, 32). Un programma affascinante.

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Come per tutti i raduni di persone negli ultimi due anni, il Coronavirus ha avuto e continua ad avere un grande impatto sui convegni del Datini. La Settimana precedente è stata completamente digitale, quella attuale è, come si dice in gergo, di natura ibrida, con relazioni presentate sullo schermo e di persona. Lasciateci essere ottimisti e considerare questa evoluzione come un passo verso un mondo reale e normale, anche per le Settimane Datini.

Nonostante le difficili circostanze durante la preparazione della Settimana, siamo stati in grado di selezionare 20 relazioni che coprono il continente europeo e una dozzina di paesi europei. I professori Markus Denzel (Lipsia) e Carlos Laliena (Saragozza) hanno portato questo interessante tema all'attenzione della Giunta Esecutiva e del Comitato Scientifico della nostra Fondazione e siamo loro molto grati. Inoltre, il Professor Laliena è stato così gentile da accettare il nostro invito a preparare e consegnare la prolusione con un breve preavviso. Lo ringraziamo per la sua disponibilità e gli diamo la parola con grande piacere.

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Carlos Laliena Corbera

The knowledge economy in the preindustrial era

1. Knowledge economy: Towards a definition*

Knowledge economy is a concept that arose in the 1990s as a result of the convergence of different traditions of economic theory around the generic importance of knowledge in the explanation of economic growth.[1] The idea that knowledge is important from this perspective predates this and had different advocates,[2] but the moment in which the group of aspects encompassed in this expression crystallised and was situated at the forefront of theoretical discussions corresponds to this period.[3] At that time it received the enthusiastic promotion from large institutions such as the World Bank and the OECD, in whose studies and planning services it acquired great importance as a general criterion of the recommendations made to member nations in order to strengthen development.[4] The importance conferred

* I would like to thank Markus Denzel, Erik Aerts, Angela Orlandi, David Igual and Hilario Casado for their help and comments, without them being in any way responsible for the statements made in this work, which is part of the Spain MICIN research project ref. PID2021-123286NB-C21 and the activity of the Reference Research Group CEMA of the Government of Aragon.

[1] The literature on the notion of the «knowledge economy» is very extensive and, in general, beyond the scope of this paper, so the references cited should be understood as a reading guide. A useful general review can be found in the first part of K. Keong Choong and P. W. Leung (2021).

[2] For instance, Fritz Machlup (1980) (which reproduces and amplifies this author's 1962 work on the production of knowledge in the USA) or Daniel Bell (1973, reed. 1999), on the importance of codified knowledge, essential in the transmission of scientific and technological information.

[3] Although these are economic theoretical models that are not always compatible and that develop different areas of analysis, the importance of knowledge as a factor of growth appears in the so-called Information Economics, Endogenous Growth Theory and Innovation Systems, which have dominated the economic landscape over the last thirty years.

[4] OECD. *The Knowledge-Based Economy* (1996) [https://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=OCDE/GD%2896%29102&docLanguage=En], where it says: «the OECD economies are increasingly based on knowledge and information. Knowledge is now recognised as the driver of productivity and economic growth, leading to a new focus on the role of information, technology and learning in economic performance» (p. 3). World Bank, *Knowledge for Development* (1998-1999) [https://openknowledge.worldbank.org/bitstream/handle/10986/5981/WDR%201998_99%20-%20English.pdf?sequence=1&isAllowed=y], which states: «economies are built not merely through the accumulation of physical capital and human skills, but on a foundation of information, learning,

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from then to the knowledge factor reached a sufficient level to coin the expression *knowledge society* and to acquire a strongly prescriptive character (Stiglitz and Greenwald 2016).[5] The economic advance, according to these institutions and the circle of influential economists related to them, was the result of applying scientific and technological knowledge to productive systems in order to increase their effectiveness, but also the implementation of forms of mainly education-based learning of individuals, companies, and societies.

From this theoretical and regulatory perspective, knowledge economy is a transversal notion that, in general, involves three complementary aspects: firstly, production and dissemination of technological and scientific knowledge; secondly, cultures and institutions that make the integration of knowledge in the productive system easy or difficult; and finally, human capital development.[6] In this way, the expansion of the knowledge economy results in the production of new goods (and the creation of new industries, in particular in the area of information and communication), advances in business organisation and the productive activity and increases in productivity that accompany these changes (Keong Choong and Leung 2021, Fig. 2).

It deals with a notion that has been said to lack vigour, in theoretical terms, because it is difficult to give it a precise content and because economists find difficulties in explaining and measuring knowledge production or its distribution. In fact, besides having a complicated definition, – what is *knowledge* and what *type of knowledge* is significant for economic activities? –[7] it is a factor that has components

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and adaptation. Because knowledge matters, understanding how people and societies adquire and use knowledge – and they sometimes fail to do so – is essential to improving people's lives, especially the lives of the poorest». (p. III). World Bank, *Constructing Knowledge Societies: New Challenges for Tertiary Education* (2002) [https://openknowledge.worldbank.org/bitstream/handle/10986/15224/249730PUB0REPL00Knowledge0Societies.pdf?sequence=5&isAllowed=y], where is affirmed: «the ability of a society to produce, select, adapt, commercialize, and use knowledge is critical for sustained economy growth and improved living standards. Knowledge has become the most important factor in economic development» (p. 7). All documents consulted 22/04/2022.

5 The authors use *learning* to emphasise the operational aspect of acquiring knowledge.

6 Expressed differently, Chen and Dahlman (2005, p. 4). According to these authors, the «four pillars» of the knowledge economy are: an adequate economic incentive and institutional regime for the development of knowledge; educated and efficient workers in the use of knowledge; an effective innovation system, in companies, universities and other organisations; an information infrastructure that facilitates the diffusion of knowledge. As they point out (n. 5) it is not necessary to have high technology or information technology to speak of a knowledge economy: new agricultural techniques or the development of logistic services also work from this perspective of applying knowledge to economic activity.

7 Debates on definition lean towards cognitive and philosophical aspects, with distinctions between «tacit knowledge» and «explicit knowledge» or, as J. Mokyr points out, «propositional knowledge» and «prescriptive knowledge» making up «useful knowledge», although in most theoretical

of a public asset, with aspects related to costs that are complex. In addition, it is susceptible to a wide affordable dissemination that is difficult to control, but, at the same time, it is subject to problems of uneven information and intellectual property rights that restrict general access.[8] Above all, however, it is very difficult to measure the dimension and the characteristics of investment in innovation, the impact of the use of technology and the effects of the different levels of education in the economic advance. Furthermore, the implementation of knowledge leads to increases in productivity that have negative social effects on employment, which is known as «creative destruction» (Stiglitz and Greenwald 2016, 199-232). There exists the added problem of «bad institutions», those that contribute to limiting the use or the dissemination of knowledge (Acemoglu, Johnson and Robinson 2005a, esp. 393-95).[9]

These theoretical problems do not daunt the great economists – who, in fact, have been awarded successive Nobel prizes, the last in 2018 –,[10] who continue having confidence in the virtuality of this concept and, it is sincerely my belief that as historians we should do so as well. With less insistence on the formal and quantitative components, as the sources pose evident obstacles for these issues in relation to the medieval and early modern periods, I am convinced that we can use the intellectual instruments associated with the notion of knowledge economy. Among other aspects, in addition to those already indicated, it is possible to utilise the concepts of innovation, technical know-how, scale effects and indirect effects and of dissemination, productivity, learning and formal education. This perspective contrasts with the idea, absolutely generalised among economists who deal with these issues, who always establish a border between the preindustrial and the industrial period at the level of 1800 which determines a radical change. Before this date, they decreed that the economies were backwards, agricultural, traditional in the most conservative meaning of the word, incapable of evolving and, above all, inadequate to provide decent living standards to the populations. Knowledge of the existing techniques was transmitted from master to apprentice, in a rudimentary form that

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literature knowledge is identified with the sum of science and technology: Rooney and Schneider (2005); Mokyr (2008, 17-43).

[8] Romer (1990, 73-75), who uses the criteria of «nonrival» and «partially excludable» for knowledge conceived as technological development: it is a public good that can be used by multiple people or firms simultaneously but is partially excludable for technological or legal reasons (e.g. through patents). On the impact of this approach, Jones (2019).

[9] In the literature on endogenous growth economic theory, knowledge-related problems of power rarely feature. Generally speaking, it is as if knowledge (science, technology, cultures and institutions) were alien to power structures in both contemporary and pre-industrial societies.

[10] Let us point to J. E. Stigliz, G. Akerlof and A. M. Spence, in 2001, and Paul Romer, in 2018, in particular.

made impossible an adequate accumulation and dissemination. Moreover, knowledge behind the technologies that they used was not based on science and experimentation, so it could hardly evolve towards higher levels.

In opposition to this simplistic form of considering growth in the preindustrial era, this Settimana will serve to verify that in the economies prior to the 18th century, a significant increase took place in the application of knowledge in produced goods and development in both technological and organisational innovation, that is to say, of 'useful' knowledge. This also means verifying the effect of the cultures, institutions and power structures on the generation of knowledge, its dissemination and its technological and productive use.

2. Knowledge in the preindustrial era and economic growth

The consolidation of the concept of knowledge economy was integrated within a more general movement, insightfully pointed out ten years ago by Paolo Malanima: the orientation of economic theory, of applied economics and of economic history towards the problem of growth in its different components and, especially, the influence exercised on it by the institutions (2011, 421-22). With this same idea in mind, that of indicating the components of growth, Paulino Iradiel recently requested paying preferential attention to the actual salaries, employment structures, urbanisation rates, agricultural productivity and total production, while he reserved a secondary role for the aspects related to growth and technology, which he considered to be effective on a micro- rather than macroeconomic level (2017, 65-68). However, a historian's typical vision of growth contrasts with the general idea of current economic theorists who, as I have indicated earlier, situate the crucial aspects of economic expansion on innovation and technology – and, therefore, on production and dissemination of knowledge.[11] This choice of the engine of growth pulls a good part of the debate to the field of the quality of technological knowledge of the past. In this way, it situates the historical moment when the take-off ocurred of the mechanisation of textile production, of means of transport and of the use of the new energy sources, which takes place, from this perspective, between 18th and 19th centuries. It is not necessary to emphasise that, in this discussion, the view towards the preindustrial period appears charged with strong pessimism. Citing a recognised author, Karl Gunnar Persson affirms that «the preindustrial era *witnessed a number of ground-breaking innovations* and improvements, but

[11] The great alternative is the explanation, also endogenous, of economic development through the effectiveness of institutions, which starts from the work of North (1990) and North and Thomas (1973) and perhaps finds its highest expression in Acemoglu, Johnson and Robinson (2005b).

they were typically generated by learning by doing. Producers learned that things worked, but had limited understanding of why things worked» (2011, 92). Under these conditions, the possibilities of increasing the technological knowledge and its application were very limited, since it dealt with inventions that were prone to remain at a technological impasse from the beginning, as Joel Mokyr suggests. Even the most important technical findings had limited possibilities of expansion due to the weakness of the «epistemic base», in words of this author (2008, 35).

It so happens that this vision, centred on inventions, inventors, engineers and scholars of learned societies, of the isolated devices and of the specific scientific advances, derives more from a cultural history of technology and, on occasion, from a history of the ideas than from an economic history. It implies great disdain for the material achievements of the period prior to the 18th century, a strongly elitist perception of technological advances – the work of a minority of enlightened entrepreneurs – and a genuine lack of understanding of the forms of knowledge transfer in the preindustrial period.[12] We will return later to this issue, but first it is necessary to do justice to the medieval and early modern craftsmen and engineers.

We can begin with the cultural environment and progress in terms of organisational knowledge. As we know, from the beginning of the 13th century, writing and the use of arithmetic in commercial, legal and administrative activities increased decisively, especially in Mediterranean Europe.[13] At the same time, the communication and information procedures associated with literacy, which do not always involve reading and writing (for example, reading in groups, visual and ritual communication), multiplied. All that we consider formal education expanded and reached numerous groups outside the social elites (Ferrari and Piseri 2013; Grendler 1989; Black 2007; Ulivi 2008; Danna, in this volume). There is no need to stress that this advance was accompanied by important institutional developments in legislation, administration, state accounting and the universities (Harding 2001; Watts 2009; Epurescu-Pascovici 2020; Ridder-Symoens 1994; Grendler 2002). Different aspects that favoured the effectiveness of commercial activities and the reduction of the transaction costs linked to written knowledge, as well as the expansion of the notary culture and the refinement of the merchants' accounting

[12] This is particularly evident in Mokyr (1993 and 2017) and Burke (2000 and 2012). For Mokyr, the period before 1750 is characterised by the resistance of institutions and social actors against the expansion of knowledge. For a commentary on this aspect, see Bruland (2007). A much broader approach to global technological evolution and implicitly critical of the reductionist view of exclusively European and post-1800 technological innovation: Schäfer and Popplow (2015).

[13] During this period, the influence of the Islamic world was essential, both in the transmission of learned knowledge (mathematical, astronomical, medical) and of certain technologies, such as ceramics. This flow of knowledge was interrupted or very limited in the late middle ages (Glick 1992).

systems gained growing importance in this period (Tognetti, 2018 and 2015; Goldthwaite 2015; Denzel, in this volume).

In the field of architecture and engineering, without a doubt the most advanced field, Stephan Epstein has indicated the enormous importance of the massive construction of cathedrals and other buildings for the creation and dissemination of a sum of technological knowledge that is visible through the considerable homogeneity of these public works. The movement of master builders, groups of masons, carpenters, quarrymen, sculptors and painters, among other experts, assured the possibility that, from one extreme to another of Europe and from the 13th century, if not before, extraordinarily precise practical knowledge was created. Knowledge that, in addition, was profiled with the passing of time and was disseminated thanks to the long duration of these centres of work, which lasted decades. It is possible that the design of these works was relatively simple, based on geometrical rules that operated on the square and the triangle, with proportions derived from very characteristic numerical symbols (Epstein 2009b, 723-24; Guerreau 1992 and 2011), but progress was evident in aspects such as the height and width of the naves or the capacity for distributing the loads, to affirming the stability of the roofs and opening the walls.[14] Moreover, the temples were not the only centres of innovation in engineering. The construction of bridges over the larger European rivers posed challenges of extraordinary magnitude, as shown by the example of the Pont de la Guillotière over the Rhône in Lyon, whose archaeological excavation allows the identification of the succession of operations carried out to erect immense works between the 14th and 18th centuries over a powerful river (Burnouf et al. 1991).

The cathedrals, castles and bridges as centres of the development of applied knowledge (Cavaciocchi 2005) were taken over by another series of areas of technological creativity at the end of the medieval era, especially mining, metalworking linked to the manufacture of firearms, and naval construction. With respect to the first, it is necessary to underscore the existence of technical improvements in the configuration of mines and wells, in the ventilation of galleries and the extraction of minerals. Metalworking benefitted from the transfer of the indirect smelting procedure known as the «forge wallonne» during the 15th century to a large part of northern Europe. High quality iron produced in abundance allowed populating the battlefields and the sieges with bombards, some of them enormous, before the rev-

[14] Bernardi's (2011, 171-87: «L'art et la science») summary is particularly interesting. It is also interesting to note that M. Prak suggests that the construction of great architectural works is an exception to J. Mokyr's distinction between types of knowledge: «the [building] industry achieved impressive accomplishments in practice, without much change in the theoretical foundations of the building craft» (2013, 133). In fact, the same could be said of many other pre-18th century industries.

olution of artillery took place with the appearance of bronze cannons that shot metallic balls. At the same time, ironwork explained in part the transformations experienced by the ships, with metallic reinforcements that consolidated the hulls and permitted an increase in size. Improvements in the design and the manufacture fostered by the creation of large shipyards where knowledge of the techniques and the interchange of technologies were concentrated, especially during the 15th and 16th centuries between the Mediterranean and Atlantic experiences which made possible not only improvements in the galleys that fought in Lepanto, but also the caravels and the large carracks that launched colonial expansion (Benoît 1988; Arribet-Deroin 2015; Ansani, 2017 and in this volume; Unger 1978; 1980, 21-32; 2020; Plouviez 2016).

3. The general frameworks of the development of the knowledge economy in the early modern period

It is not difficult to conclude that the elements inherent to the knowledge economy that I indicated at the beginning – the implementation of new technologies, the formation of cultures favourable to their dissemination and the qualification of craftsmen and engineers – explain in part the relatively rapid economic recovery after the epidemic crises and the European wars of the 14th century.[15] From this scenario, it is necessary to consider six large problems related to the application of knowledge to the European and, later on, colonial production systems that made possible the early modern knowledge economy: the mobility of the merchants and experts, the expansion and integration of markets, the formation of social networks and the strength of craft guilds, the growth of written communication, urbanisation and the involvement of the States. Each one of these aspects, which simultaneously involve techniques, cultures and institutions, are immeasurable for which reason only some indications about them can be made here.

The movement of qualified manpower, which constitutes the first of these aspects, has been a subject of traditional study among historians of the countries, regions and cities receiving the specialised craftsmen and among those who provided this type of immigrants. Every existing late-medieval or early modern trade, manufacture and industry that had some type of technological advance participated in the

[15] An overview, Braunstein 2011. There are alternative explanations, based on the development of institutions favourable to trade and economic expansion: in general, Epstein 2009b; and, for a more concrete analysis, Yun-Casalilla 2019.

migration of workers equipped with the appropriate technical knowledge.[16] It is what occurred with the Italian merchants in Spain (Igual 2007) or in France, in particular in Lyon (Tognetti 2013), countries where they had great influence in the transfer of technical knowledge, even if only with reduced groups.[17] It is important to point out that the resistance of the guilds to integrate the immigrated qualified craftsmen was limited (Franceschi 2019). The mobility of the craftsmen depended considerably on the characteristics of their specialisation. The skilled persons of the textile industry of Ausgburg at the beginning of the 17th century came from a large region of its surrounding area, including other cities. Many of them had prior training and others acquired it in the city. It is interesting to note that the flows were inverted in the 18th century, when the textile activity expanded in rural areas which applied the knowledge acquired in the city, through the creation of guilds, workshops and the application of processes and qualities similar to those existing in the urban area. The overall production suffered, but the benefits of this manufacture were disseminated (Reith 2008, 121-22). Perhaps the most significant example of the knowledge transfer through geographic movements is that of the silk industry. As we know, the diaspora of merchants and craftsmen from Lucca favoured the creation of new production centres of this type of fabric, in particular in Venice (Molà 1994, Franceschi 2012, 84-90), but also in the Iberian Peninsula, especially in Valencia (Navarro 1997). In a later phase, during the 16th and 17th centuries, the movement of silk craftsmen in northern Italy led to first-rate industrial development based on the intensity and dissemination of technological innovation and the transformation of the types of silks (Belfanti 2004).

From the late middle ages, an exceptional extension of the mercantile systems took place, from the geographic and organisational viewpoint as well as of the goods.[18] The incorporation of the colonial worlds to these circuits releases us from trying to give more arguments to the idea of a first globalisation of the exchanges and, with them, of knowledge in all its facets. But even within the confines of Europe, international traffic grew rapidly and the improvements in transportation – especially maritime transport, thanks to the navigational techniques and construction of vessels– were immensely effective. The mercantile knowledge and the banking techniques, especially those related to public credit, reached the entire

[16] General approaches in the framework of a vast literature: Cavaciocchi 1994; Fontaine 1996; Pizzorusso 2007, which situate specialised migrations within broader contexts, in particular temporal movements and the influence of states and institutions.

[17] In addition to technical know-how, the diffusion of a luxury material culture, especially by Italian merchants, was important: Orlandi 2019.

[18] In general, Casado 2011; Epstein 2009a.

European area, far from being concentrated in the Mediterranean world (Guidi Bruscoli 2007). Directly connected to these practices, state-designed governance of currency was increasingly more precise and sophisticated (Lanza 2019). The creation of international trade shows of a financial nature was added to the advance of the multilateral payment forms, with capacity to transfer large sums of money, especially to pay for continental wars (Epstein 2009a, 103-21). Despite these conflicts, it is probable that the transaction costs fell as the European States turned to more efficient fiscal and banking systems (Orlandi 2002; Fortea 2019), accompanied by tangible progress in the field of information. Lastly, the integration of the markets was a consequence of the transformations of the consumer society, which tended to increase and make popular the traded goods (Kowaleski 2006; De Vries 2009).

The importance of the craftsmen's guilds in the dissemination of knowledge in the early modern period has been the subject of long discussions, which have evolved slowly towards a vision less pessimistic than that which presided over traditional historiography. In the words of Epstein and Prak, the guilds were institutions that «(...) helped reduce transaction costs in at least three distinct, significant stages of the industrial process. First, by creating a stable environment, which encouraged craftsmen to invest in training the successor generation. Second, through the coordination of complicated production processes. And finally, in the marketing stage, through the reduction of information asymmetries between producers and customers» (2008, 1-24, quote, 4). The first of these authors has systematised some of these points. He points out that the principal explanation of the universal existence of the guilds in Europe and their prolonged persistence is rooted in the control of the masters over the skilled workers and apprentices, especially in order to guarantee the quality of the apprenticeship and to avoid opportunism from these workers via sanctions. By impeding the movement of apprentices between workshops to improve their remunerations or by reducing the authority of the masters over them, the guilds assured stability in the training process and transfer of technical knowledge that resulted in a homogeneity of the skills of these apprentices. In addition, they also protected the young workers, ensuring their appropriate training, as well as other forms of instruction. Furthermore, Epstein insists that the argument that the guilds opposed technical progress through oversight and the rigidity of the productive procedures is inconsistent. Supervision was limited, technical innovation was difficult to control and there was considerable leeway for the workshops to introduce changes using new techniques without being penalised. Besides, the innovations that saved manpower tended to harm the poor craftsmen, who had less political capacity within the guilds, which explains that the opposition was relatively weak. The State, the cities and the merchants were also able to break down this resistance. Consequently, the guilds were not as impervious to technological change or the dissemination of useful knowledge as has been sustained without sufficient basis (Epstein 2008; Casado 2004). The key factor in the relationship between guilds and useful knowledge is the importance of apprenticeship as the fundamental institution in the transfer of knowledge in the preindustrial era. Intergenerational circulation of knowledge implied somewhat more than the simple development of human capital from the moment it also involved cultural aspects, such as the capacity to produce goods with a quality determined by factors that were not exclusively economic (De Munck 2007).

In fourth place, it is known that, at the end of the middle ages, the production of manuscripts in series had reached certain circles, such as the universities. However, this type of materialization is incomparable with the impact of the printing press which, by itself, brought about a radical change in the volume of information and in the speed of its dissemination during the 16th-18th centuries. During this period, the printed materials were quite diversified, ranging from books to pamphlets or newspapers, creating broad and varied channels for transferring knowledge. Part of these documents were applied to expanding science and even the techniques through treatises and more or less encyclopaedic works (Blair and Fitzgerald 2015). As we will see, all of this was essential for the scientific revolution of the 17th century, but it is more difficult to verify its economic potential. There is no doubt that information in the broad sense was basic for the merchants and for the State governments, which explains the creation of the postal services and archives, but the form in which it influenced the productive systems is less evident. The development of the colonial empires exacerbated the need to have in-depth knowledge about distant realities outside the European experience with the aim of exercising power over them. This creation of knowledge about the colonial world had endless useful applications, such as those related to botany, cartography or navigation systems, but its application to the productive economy is not easy to measure (Brendecke 2012; Carrió Cataldi 2016). However, it can be said that the expansion of general, cultural or tacit knowledge constitutes the ecological means in which the techniques of the early modern period were developed.

Something similar occurred with the last two aspects that we are going to examine. The importance of the cities in the elaboration of knowledge, especially technical knowledge, is unquestionable. The urbanisation rate of early modern societies grew extensively, the regional urban systems grew in density and some European cities expanded until reaching the rank of world metropolises, such as London or

Paris. The cities concentrated the economic, cultural and political institutions, in addition to becoming the basic infrastructure of the national States. The commercial networks unified the urban systems and connected them with countries outside of Europe in a phase of intense globalisation. The economic growth was increasingly the result of production of goods and merchandise in the cities,[19] in such a way that the proximity between the workshops facilitated the reduction of costs, collaboration between the craftsmen, dissemination of knowledge and transfer through apprenticeship. The city strengthened the development of human capital through formal and informal educational institutions, such as schools, orphanages and asylums for children and poor workers; the city-based guilds fostered the teaching of the techniques of the corresponding crafts. The immigrants that moved between cities transferred with them their technical resources and initiatives, without the restrictions that they occasionally came up against being sufficient to avoid this transfer. The cities granted privileges and monopolies that stimulated the success of some industries, especially those related to luxury. Hybridisation, innovation and creativity were patrimony of some cities that accumulated innumerable objects that carried with them the technical information on how they had been produced. And the cities were subjected to continuous physical renovation –spaces, buildings, churches, palaces and other headquarters of power– which led to intense circulation of knowledge (Davids and de Munck 2014; de Munck and Romano 2020; Klein and Spary 2010).

Lastly, we must underscore the effectiveness of the State in the promotion of knowledge. As occurred with cities or communication, the State is in turn a participant in the drive for innovation and the institutional context that contributes to expanding it. The European States, regardless of their form and dimensions, generated knowledge. Their bureaucracies gathered information, as we have seen, with the aim of intervening in the social body. The State accumulated power and the power was expressed in multiple forms at the heart of the economy and knowledge. Perhaps the most evident is the granting of patents to the inventors, a procedure with medieval precedents that the Venetian State organised in the most perfect way at the end of the 15th century (Belfanti 2004 and 2006). During the early modern centuries, the idea of granting benefits in the form of monetary compensation or temporary exclusivity in the enjoyment of the income derived from an invention reached all the States and many European cities. Among them, Colbert's France stands out, whose bureaucracy made an enormous effort to control inven-

[19] This urban leadership does not contradict the considerable importance of rural protoindustries in this period (DuPlessis 2001: 261-347; Marfany 2012).

tions, both through administrative registration and through verification of the effectiveness of the inventions or technical innovations by men of science. Not only was it done in a centralised manner – in Paris – but also in the provinces, where the mayors promoted experimentation and the technological change on the local level (Hilaire-Pérez 2000, 39-142). In theory, the patents restricted the expansion of knowledge by establishing monopolies on the discovered techniques, but in this period imitation and hybridisation left little margin for preserving technological secrets and this type of awards was hardly a deterrent to the dissemination of knowledge (Degrassi and Franceschi 2018).

The creation of the national schools of engineers at the end of the early modern period was the culmination of a mobilisation of experts in weaponry and fortifications that was massively recruited by the States. The publication and translation of treatises on these subjects is the best possible expression of this circulation of specific knowledge based on mathematics and geometry for the construction of forts, their siege and resources, especially artillery, necessary for defence and attack (Spicq and Virol 2016; Virol 2016). These treatises constituted the theory, which can be referred to as codified knowledge, but the practice is equally evident, in view of the enormous quantity of urban fortifications and border forts in the Low Countries, France and the Empire, not to mention those erected in the Spanish colonies. The States were deeply involved in the application of this architectonic knowledge and the architects and engineers could learn simply from observation and imitation of the existing constructions. Any reservation on the exceptional economic dimension of this intense utilisation of useful knowledge is misplaced (Parker 1996).

The large fortification systems that proliferated throughout the continent are only one part of the investment in military technology. From the Hundred Years War to the Napoleonic Wars, the military conflicts were incessant and the European States mobilised human resources, economic means, military specialists and, above all, weapons technologies. Firearms and war ships were the most important of these technologies, which were subjected to continuous improvements through minor but accumulative technical changes. The result was not only greater effectiveness of these weapons, but also a dramatic reduction in costs and an increase in their production. These advances, furthermore, were the work of different types of craftsmen who combined their skills in order to increase the efficiency of the weaponry. It is not really necessary to say that none of these experiences in the fabrication of weapons were secret or could be kept out of a very rapid circulation of knowledge.

The European States, or perhaps better stated, the kings of the early modern world were surrounded by splendour, pomp and, among the most spectacular manifestations, the palaces stand out, not only for their extraordinary outlays for their construction, but also for the expenses in their decoration. To cite just one example, the Buen Retiro palace of Madrid cost around three or four million ducats, equivalent to 3-4% of all the expenses of a monarchy with world interests during the decade of 1630-1640. From all that, an important part was allotted to furniture, tapestry, paintings and works of art, clocks and, in general, objects of an exquisite manufacture (Brown and Elliott 1981, 99-109). Demand at this level and quality stimulated the production of ostentatious consumer goods and fostered innovation in this type of industries, which was applied later to productions of a lower economic level and greater popular scope, as occurred with the clocks (Landes 2007). In addition, royal courts were converted into centres of attraction of technical innovation, in particular, Versailles, where the investors were welcomed with a patronage that extended widely from the royalty to the aristocratic elites (Hilaire-Pérez 2000, 226-32).

In conclusion, from the viewpoint of the knowledge economy during the late middle ages and early Modern period, it is necessary to insist that it deals with a period in which there was a continuous circulation of technological knowledge that led to a hybridisation of knowledge, a creative imitation or adaptation of techniques, and that this dynamic had a global dimension. It is increasingly more evident that the European advances explicitly or tacitly appropriated knowledge coming from the Asian and colonial worlds. Part of this knowledge was included in the objects, in the imported material culture that posed a technical and quality challenge for the European craftsmen. But this capture also resulted in research, in scholarly work, travellers, merchants, military personnel and public officials who discovered materials, processes, designs and production systems distinct from the European ones, as occurred with the cotton fabrics from India and their influence in England (Berg 2004 and 2013). This circulation intensified within Europe from the late middle ages due to the succession of large regions where the accumulation of technological changes in specific industries occurred. Northern Italy and its engineers of the 15th and 16th centuries gave way to Central Europe's development of steel and mining and this in turn to the Low Countries' light textiles and luxury productions, and from there to Colbert's France, and to the textile manufacturing of 18th century England.[20]

[20] This succession is frequently cited; among others see Epstein 2009b, 717-18.

Secondly, the development of new global markets, of new cultural expectations and of new consumer practices created a demand for luxury and semi-luxury products, such as, to cite some examples, silk, enamelled ceramics and porcelain, glass, and oil paintings. The history of each of these products illustrates the complexity of technological innovation, knowledge transfer and the local adaptations in the framework of already existing technical cultures. It is evident that it dealt with relative innovations – since silk, ceramics, glass and paintings existed previously – and that their dissemination was done through both traditional and innovative channels, in particular, the mobility of the craftsmen and the painters, but also through the development of retail stores for this products (Blondé, Stabel, Stobart, Van Damme, 2006). However, the introduced improvements gradually reduced their price and popularised them, created economies of scale and increased their marketing, as occurred with the Dutch genre paintings of the 17th century, converted into an everyday object in the bourgeois homes of the Netherlands or the silk fabrics that enormously increased their clientele (Molà, Mueller and Zanier 2000; Goldthwaite 1989; Finlay 2010; Maitte 2014; Nuttall 2004; Bozal 2002). The late middle ages and early modern knowledge economy is integrated deeply in the formation of a preindustrial consumer society.

Finally, it is important to consider that the innovations and dissemination of technical knowledge were frequently presented as «technological packages» that included different interrelated components. A classic example is printing, which required fabricating new inks different from the medieval ones and it required improving the production of paper (Johns 2010; Cavaciocchi 1992). There was another type of integration, such as that which united ships and cannons, as described hitherto by Carlo Cipolla (1965). This integration imposed significant technological changes on both fields, shipbuilding and the manufacturing of cannons. In reality, nearly all the productive activities coordinated different elements that were, up to a certain point, independent, but the sum of all of them noticeably increased the economic and cultural impact – or, such as the example of the cannons and the sailing ships, the power – and, therefore, the result can be classified as technological innovation.

4. Knowledge transfer in the preindustrial era

In the 17th and 18th centuries, a better and cheaper access to knowledge thanks to printing led to the gradual transformation of the oral tradition in the transfer of technological knowledge to a written and also progressively scientific form, of which the publication of numerous encyclopaedias and technical treatises has been a good demonstration. Joel Mokyr has proposed with some success the concept of «Industrial Enlightenment» for this movement that affects the European intellectual elite in the second half of the 18th century (2008, 45-89 and 2017). An elite that was united virtually in a «Republic of Letters», based on the exchange of information among scholars in order to register and codify the existing technology, explain the functioning of the different techniques that comprised it and increase its effectiveness through a growing development of inventions and machinism. In accordance with this approach, the Industrial Enlightenment was at the base of the Industrial Revolution[21] by decisively transforming the prior useful knowledge, expanding its epistemic bases so that it was no longer based on trial and error or in the recipes transmitted from master to apprentice.

The arguments of this author have been partly completed and also partly revised by Jan Luiten van Zanden (2009), who situated the origin of the knowledge economy that took place in the Industrial Revolution in the development of efficient institutions in the medieval period that favoured a growing accumulation of comparable knowledge through the increase of the production of fundamental goods in this regard, such as books. In second place, he indicated that this progress continued during the 16th to 18th centuries and that it is possible to measure it thanks to the evolution of the remuneration of specialised work (*skill premium*). The reduction of the differential between the salaries of specialised workers and those not specialised indicates high levels of human capital development and, consequently, it is an important factor in detecting economic growth. The drop in this differential during the late middle ages and its later stabilisation during the early modern period suggested that the training mechanisms of the European employees worked. The increase in production and the drop in the price of books served this author to verify the high educational level – equivalent to literacy– of the human capital, especially in northern Europe – Great Britain and the Netherlands.[22] With these arguments, Jan Luiten van Zanden justified the progress in the qualification of human capital. The comparisons with the Mediterranean and Asian regions per-

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21 «By the middle of eighteenth century the attitudes toward technology-driven material progress had changed dramatically, a phenomenon I have called in early work the Industrial Enlightenment and wich was a foundation of Industrial Revolution» (Mokyr 2017, 142). On the «Republic of Letters», open science and the feeling of belonging to a community of European intellectuals, Mokyr 2017, 180-224.

22 Classic studies by Carlo Cipolla (on literacy) (1970), Alfred W. Crosby (on quantification) (1998) and Federigo Melis (on commercial accounting) (1991) have shown the cultural background against which human capital formation evolved since the late middle ages. As Jan Luiten van Zanden has put it, «the hypothesis is that consistent with endogenous growth theory (and unified growth theory), increased knowledge accumulation and increased investment in human capital through education preceded the emergence of modern economic growth» (2009, 8).

mitted him to underscore the advantage of northern Europe and explain the geographical-time location of the decisive turn that Mokyr proposed at around 1750.

This great narrative has been criticised as being Eurocentric and even Anglocentric and for underestimating the importance of the forms of knowledge transfer and their technological and economic dimension of the preindustrial era (Carnino, Hilaire-Pérez and Kobiljsky 2016; Hilaire-Pérez and Verna 2009). In this respect, S. Epstein and M. Prak have shown that the transfer of technical knowledge through apprenticeship was a very effective mechanism, relatively cheap and adaptable, which explains its lasting nearly a millennium. [23] It served to transfer some technical knowledge and manual expertise whose acquisition took years and that was difficult to codify or teach in any other way. In particular, the attempts to compile treatises in the early modern period suggested that its authors omitted a very important part of the information from the text because they relied on the result of the skills of the craftsmen. The same occurred with the patents, whose history runs all through the early modern era, which did not guarantee the exclusivity of the protected procedures. In this context, the craftsmen's guilds ensured the quality of apprenticeship and regulated the admission of immigrants who contributed new knowledge and new products. Except in fields in which chemistry was basic, reverse engineering was almost always possible and technical secrets difficult to keep. That explains the institutionalisation of the master-apprentice model and also the wide cooperation among engineers, architects and qualified craftsmen (for instance, Ibáñez and Zaragozá 2017). The advantages of open knowledge fully exceeded the possibilities of obtaining benefits by hiding findings.[24] In addition, there always existed sites of labour concentration that fostered this horizontal dissemination, such as the large architectonic works, the shipyards or the metalworking centres. A knowledge transfer was also derived from the migration of specialised craftsmen, as we have indicated. Their mobility made it possible for them to find places where their technical skill gave them a temporary competitive advantage over the local workshops, before their knowledge was disseminated and the advantage disappeared. These migrations were encouraged by the States and cities that favoured the incorporation of specialists in fields with high demand, from silk-making to weaponry. Others, such as that of the painters or architects, depended on a semi-public, but always intense, demand, such as that which affected the German master builders or architects in the

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[23] A much more critical view of the effectiveness of guilds in human capital formation and innovation in Ogilvie 2019: 354-510.

[24] This idea is implicit in the notion of «disegno rinascimentale» as a fluid circulation of knowledge about the characteristics of luxury products in fifteenth- and sixteenth-century Florence (Nigro, 2020).

15th century. In summary and in the words of Stephan Epstein, «notwithstanding the absence of much written evidence, evidence from technical practice suggests that pre-modern non-scientific technical knowledge expressed significant degrees of abstraction, experimentation and cumulation.» (Epstein 2009a 743; Epstein and Prak 2008).

Liliane Hilaire-Pérez (2007) reached the same conclusion, defending the artisan culture in the transformations that took place in the 18th century. The capacity of the craftsmen was not only a sum of specialised skills, but rather it included sufficient intellectual resources to develop new products and modify them according to consumer demand. Furthermore, the craftsmen practised forms of open knowledge and competed in the markets, which signified a marketing of knowledge. In the Age of Enlightenment technical schools began to operate, many craftsmen acquired transversal skills and the State as well as the guilds and municipal governments awarded and financed technological inventiveness, as shown by the well-known example of silk-making of Lyon. Hilaire-Pérez added that the complexity of the manufactured objects grew considerably and created new forms of organisation, cooperation and division of labour: the material culture favoured the open knowledge of the techniques. Lastly, this knowledge was disseminated through public demonstrations such as shows and fairs above all, thanks to printing. Both dissemination processes extended beyond the sphere of the craftsmen and permeated the consumers who acquired wide knowledge of the technical conditions of producing goods.

In some respects, the consensus on the idea that in the 17th century a "Scientific Revolution" took place at a European level that set the bases for the expansion of science in the following century can be considered as a criticism of the unique and revolutionary character of the Industrial Enlightenment and, in general, of the scientific development linked exclusively to the Late Enlightenment. This intellectual innovation process was fed by the printing works, the multiplication of scientific societies, the intense communication among cultured persons and the influence of the first globalisation. This Revolution relegated to a discrete obscurity the classic and medieval tradition on nature and it produced decisive changes in different disciplines, from astronomy to medicine, which could not be separated from the general preindustrial knowledge expansion movement that we have described (Burke 2000, 38-44).

5. Productivity, risk reduction and human capital formation in medieval and early modern centuries

As occurred in many aspects of the economies of pre-statistical societies, it is difficult if not impossible to quantitatively measure the effects of the application of knowledge in the production of goods. The effectiveness of a new technique or device is rarely measurable, nor is the qualification of the workers and their productivity. This is not rare, among other reasons – as we indicated at the beginning – because the characteristics of knowledge even at present make it very difficult to measure the benefits of the educational policies on the increase of productivity in a specific country or to separate this factor from others that coincide in this growth. Outwardly, the results of the application of new technologies or specific inventions are more evident, but even here it is not easy to evaluate the part of the productivity that depends on innovation and that which comes from the training of the workers that put it in use. Without extending these considerations, it is obvious that some medieval and early modern inventions revolutionised productivity in certain industries, such as the spinning wheel in silk production, especially when hydraulic energy is applied to it (Crippa 2000, 16-22). In other cases, new products were created whose importance is difficult to exaggerate. Therefore, to cite one among an endless number, the printing press, besides launching onto the markets large quantities of books, made possible the appearance of a peculiar item in sixteenth-century Spain, the *Bull of the Crusade* or indulgence, a paper document that offered a waiver of sins to whoever bought them, for themselves or for their deceased family members, and whose sale was divided between the pope and the crown. Between 1509 and 1513, the printing presses of three monasteries of Castilla manufactured a minimum of six and a half million of these papers that produced income for the Spanish monarchy during these four years equivalent to a third of its budget (Ladero 2019). The possibility of printing the bulls transformed a rare and unusual item, the papal indulgence, into an inexpensive product –if you can refer to alms in this way– and accessible to the entire population, which was put in contact with a written text loaded with symbolic content.

Some sectors of the economy are more prone than other to verifying these advances in productivity. In particular, the textile industries show the complexity of the adaptations of the different types of fabric to the expectation of demand, producing a considerable variety of mixed products of cotton, silk, linen and wool in very diverse proportions but, in any case, light and capable of supporting dyes and printing that satisfied the consumers. The European consumers were particularly attracted by the cotton fabrics coming from India – which could only be imitated with fabrics partially made with cotton, since this raw material was expensive in Europe, as were the salary costs –, but also the participants in an African 'market' organised around the slave trade. John Styles (2022) has shown the effect of this growing demand on the ingenious combinations of fibres hidden under the general term of "cotton" which come from a hybridisation model characteristic of this type of industries from the medieval period, but also the influence exercised by consumer interest in velvet, stockings, muslins and calicos in the creativity of the British inventors of the second half of the 18th century, in turn supported by slave cotton.

The Florentine case, studied by Francesco Ammannati and other authors, is interesting in this context, since it shows the failure of an industry clinging to a traditional productive model that had its days of splendour in the late middle ages, but which lost competitiveness from the end of the 15th century and shunned introducing innovations that could have improved it. The decline in the production of wool cloths in Florence has long been known as well as some of the factors that provoked it. The increase in the price of quality wool and the reduction of the supplies were important aspects, as well as the defence of a solid currency that impeded reducing the prices. But the main weaknesses, as this author pointed out, were the rather inefficient organisation of the companies, the very low productivity of labour and no innovation, both in the productive systems and in the types of fabrics offered to the consumers. The elite group of textile businessmen refused to adapt to a demand that wanted lighter wool cloths and that favoured silk, linen and cotton in the products of different qualities. The solution of reducing the salaries of the Florentine workers was not sufficient to mitigate the absence of the elements typical of the knowledge economy: technical innovation, organisational culture, development of human capital and institutions that promoted the application of knowledge (Ammannati 2020; Malanima 1982). Surely other manufactures could be entrenched in their traditional techniques, and it is also probable that in many European regions the persistence of rural industries was sufficient to cover a good part of the demand, but this example highlights that the evolution fostered by knowledge was inevitable in many other production domains.

Similarly, the cultural formation of medieval and early modern workers, or, to put it another way, the characteristics of this aspect of human capital, its measurement and influence, is a debated issue. If we leave aside the aspects included in master-apprentice learning – controlled by corporations to a greater or lesser extent – literacy and years of schooling are usually the factors that justify the increase or decrease in the general training of workers in the pre-industrial era. This approach is based on the premise that a higher cultural level predisposed worker to make better use of technical resources, to be more productive and efficient, and to better transmit their knowledge to their peers and apprentices. From this point of view, there is a growing consensus among historians about the relatively high rate of schooling of both city dwellers and peasants before the 18th century, including the medieval period, a rate that declined during the first phase of industrialisation.[25] We should probably retain the idea that, in general terms, the printing revolution and schooling promoted the further upskilling of European workers.

In this regard, this set of economic factors that we encapsulate in the «knowledge economy» formula promoted the resilience of the European medieval and early modern societies towards the severe demographic, economic and military crises they had to face from the 14th to 17th centuries. Growth – unequal and very different according to the large regional areas of Europe – of this period was based on innovation and technology, basic components of the endogenous growth through the increase in productivity and the decrease in risks. It was also a consequence of the renewal of the institutions and the decrease in transaction costs, as suggested by other historians, which promoted the development of trade worldwide. In this level of abstraction, these large theoretical models have multiple aspects that are difficult to separate in reality, as is evident. But productivity and risk are not minor problems and it will be sufficient to indicate that the Third Settimana Datini was dedicated fifty years ago to the *Produttività e tecnologie*, a precise indicator that economic historians continue to be concerned by these crucial issues. It is appropriate to point out, however, that in the congress proceedings of the cited Settimana, none of the authors used the concept of "knowledge" and they focused on agricultural yields, technological devices and organisational efficiency, but they did not ask themselves about the conditions of creation, accumulation and transfer of useful knowledge.[26] This observation is a measure of the need to respond to the questions that we have proposed on the cultural processes of dissemination of knowledge, the social and institutional networks and the characteristics of the development of human capital in the preindustrial era, essential in order to verify two things: the first, that all of that served to promote economic growth processes of diverse nature during the preindustrial era, and, the second, that the scientific and

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[25] In addition to the references already indicated, Derville 1984; De Pleijt 2018. For the development of arithmetic knowledge in medieval period and 16th century, Danna, 2022. For books production and human capital formation, van Zanden 2009, 69-91 and 178-201. It is interesting too Rideau-Kikuchi 2022.

[26] Mariotti 1981. The Settimana took place ten years earlier, in April 1971. The secondary role of knowledge, innovation and technology is very visible in Hermann van der Wee's synthesis at the beginning of this volume (1981, 9-16).

technical transformations that began to take shape around 1800 are sustained on the knowledge economy that dates back to the medieval period.

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La conoscenza utile e la sua diffusione

'Useful knowledge' and its dissemination

Julia Bruch

Transmission of useful knowledge in texts written by craftsmen. Two case studies from the Holy Roman Empire

1. Intro

For mastering a craft successfully, not only talent and suitability of skills were required but also a solid education.[1] The knowledge required for the practice of a craft was passed on in workshops (Reith 2005, 356-58). According to Mokyr, the practical and technical knowledge conveyed in workshops can be defined as useful knowledge in the meaning of «prescriptive knowledge» (Mokyr 2011, 4). Prescriptive knowledge of craftsmanship has to be transmitted from one individual to another and is mostly embodied and tacit knowledge,[2] which is difficult, forbidden, or even impossible to write down.[3] Craftsmen were forced to learn, depending on the degree of difficulty, through countless repetitions of the concrete activity. Instructed and, if necessary, corrected by a master of the profession directly in the workshop. Complex crafts such as gemstone cutting or the plating of harnesses entailed comparatively many years of apprenticeship but also a later field of activity that could be very lucrative.[4]

Nevertheless, craftsmen usually went through the city schools and learned to read and write in the vernacular and to do calculus. Some also learned Latin (Bernoulli 1890). It can be seen that guilds used written documents for legal and organizational regulations. In guild books kept by masters since the 15th century we can find rules, statutes, lists of members, accounts, and so on. The written form was therefore directly related to the guild's organization and administration; concrete craft knowledge about how the respective products were manufactured was not

[1] I would like to thank the members of the Datini Conference 2022 for the discussion, Andreas Lehnertz for the fruitful exchange of ideas, and Johanna Ecker and Carolin Schmitz for their help with the English language.

[2] «In this kind of model the social nature of knowledge is central: learning or diffusion would be defined as the transmission of existing knowledge from one individual or device to another» (Mokyr 2011, 5); cf. Mokyr 2011, 9-12 on transmission of prescriptive knowledge.

[3] On the connection between embodied knowledge and writing cf. Smith 2010, who also offers a definition. She uses the term «practical knowledge» (Smith 2022).

[4] Apprenticeship years could vary, usually lasting two to three years (Heusinger 2009, 62); complex crafts could significantly exceed this time (Brugger-Koch 1985, 7-8). In the cities of the late middle ages and Early Modern Period, the training periods for professions were regulated by guilds and outlined in guild statutes (Heusinger 2009, 61-64, 115 f.).

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Referee List (DOI 10.36253/fup_referee_list)
FUP Best Practice in Scholarly Publishing (DOI 10.36253/fup_best_practice)

Julia Bruch, *Transmission of useful knowledge in texts written by craftsmen. Two case studies from the Holy Roman Empire*, © Author(s), CC BY 4.0, DOI 10.36253/979-12-215-0092-9.05, in Giampiero Nigro (edited by), *L'economia della conoscenza: innovazione, produttività e crescita economica nei secoli XIII-XVIII / The knowledge economy: innovation, productivity and economic growth,13th to 18th century*, pp. 35-58, 2023, published by Firenze University Press, ISBN 979-12-215-0092-9, DOI 10.36253/979-12-215-0092-9

recorded. Merely in the margins, in the guilds' pragmatic literature, and in the legal writing of the city council, knowledge about the craft activity was at times revealed. For example, if a certain type of craftsmanship was to be used or not used, a certain product was to be made or not made. For instance, the Venetian gem cutters were not allowed to produce glass, the textile producers were required to use a certain number of threads, and the Augsburg harness makers had to produce in Augsburg (Brugger-Koch 1985, 4-6; Gamber-Becher 1980, 44 f.). Nevertheless, the focus was not on the transmission of craft knowledge but on the product's quality assurance.

However, it is evident that writing was widely used in the workshops as well (Rösler 2010). Chronical writings display that craftsmen were able to acquire a complex written form in order to compose intricate writings beyond pragmatic administrative action and bookkeeping. Last but not least, the late medieval and early modern Meistersingers show that literary writing was even encouraged among craftsmen (Bruch 2019; Hölscher 1903; Dehnert 2017).

Thus, knowledge was transmitted orally and practically and it was argued that this oral transmission, flanked by legal regulations, led to a stagnation of innovation. Because useful knowledge was always passed on within a workshop, it was assumed that it proceeded very statically and that innovations only came about slowly through testing and reinventing evolutionarily in each individual workshop. The craftsmen only learned what their master knew. However, this was countered by the fact that the guilds had found their own way out of the dilemma. The problem was not solved through writing but through craftsmen who had completed their training. They would work for other masters in foreign workshops and thus travel through the area. This constant exchange between cities and regions helped to spread innovations and even encouraged new developments. Thus, useful knowledge and skills were transported via individuals[5] and the exchange of knowledge took place beyond the individual workshops. Moreover, a lively social and professional exchange due to the great geographical mobility of the journeymen, who moved from town to town and worked in other people's workshops, can be proven (likewise through voluntary and involuntary long-term migration).[6] However, there were also efforts to protect economic advantages that certain techniques brought with them from exchange. In Nuremberg, for instance, the exchange of staff with the outside world was prohibited (Stahlschmidt 1971, 161-63).[7] In the long run, this strategy proved to be less efficient as external impulses were less intense than in cities that promoted exchange (Reith 2008, 141).

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[5] Reith 2005; 2008. On mechanism of prohibition and dissemination of craft knowledge see also Belfanti 2004.

[6] Travel routes of journeymen and, on the other hand, employment lists show very clearly how extensive this exchange could be (Schulz 1996).

[7] In Solingen, the bladesmiths, hardeners, and grinders had to take an oath not to disclose the secret of producing blades. Schwertfeger, who were in charge of the final assembly and therefor involved in the production process, remained exempt from it (Beck 1884, 847-51).

In sum, the skills that craftsmen would have needed to record their knowledge were given since the late middle ages. Why didn't craftsmen write about it? The first answer is simple: it was not necessary as the knowledge was transmitted to the apprentice by the master. It was practical knowledge, which did not provide any benefits when put into writing. However, this narrative is contrasted by countless surviving craftsmen's manuals mainly for building, fireworks, war machines, painting, and barbering. These books convey knowledge about craftsmanship and were printed early, at the latest in the 16th century. Furthermore, these written and printed recipes and technical books became accessible beyond the own craft.[8] If these books were apparently not needed for knowledge exchange within a craft, why were they written? And vice versa: did the knowledge conveyed play any role for the transfer of useful knowledge and spread of innovation within the craft community and beyond? These questions are related to actual debates about artisan writing and the transfer of craftmanship knowledge.[9] The sources have so far been rather neglected for economic-historical questions while interesting results have already been delivered by studies in art and architectural history, costume history, military history, history of technology, history of medicine, and history of knowledge (Leng 2002a; Smith 2010; Holzer 2021; Lindgren 2000; Oltrogge 2013; Schütte 2019, 131-3).[10]

I would like to apply this cultural-historical research on handicrafts and writing to questions of economic history. In this article, I would like to approach the answer to the raised questions with the help of two micro-studies on manuscripts written by craftsmen from the 16th century: a manuscript containing information about plate harnesses written by an etcher from Augsburg and a book about casting techniques written by a bell founder from Munich. For the analysis I will use the historical-critical method combined with the manuscripts' analysis. For a better understanding of the manuscripts' variability, I rely on two detailed studies. I have chosen two manuscripts which come directly from the workshops of the craftsmen who wrote them and can be directly linked to their products. This direct link between product and writing is not always verifiable. Moreover, both crafts belong to those metal crafts that specialized in the production of expensive luxury objects.

2. Type(s) of Sources

Writings that convey craftsmen's knowledge are divided into different source genres, whose classification criteria overlap. Most often, the sources are divided into model books (Musterbücher), master builder's books (Werkmeisterbücher), recipe books and books on pharmacy, as well as treatise on military engineering

[8] According to Mokyr, technical manuals require knowledge to be decoded from users (Mokyr 2011, 11).

[9] These questions were inspired by Pamela H. Smith' pioneering works (Smith 2010; Smith 2022).

[10] These manuals appeared even among Jewish craftsmen. I thank Andreas Lehnertz for the reference to manuscript Munich, Bayerische Staatsbibliothek, *Cod. hebr. 235*.

(Büchsenmeisterbücher) and gunpowder (Feuerwerksbücher) (cf. Gabriel 1977; Keil 1980; Beate Braun-Niehr 1993; Keil 1995; Binding 1997).[11] All these sources have in common that they can be called «professional literature» or «technological treaties» and convey craft or professional knowledge (Lefèvre 2004).[12]

Since the high middle ages, manuscripts conveying knowledge about crafts have been known, first sporadically, then increasingly. The text *De diversis artibus* (On various arts) by Theophilus Presbyter,[13] which was written around 1100-1125 and describes various techniques of medieval craftsmanship, can be named as a very early example. In this text the goldsmith's art, book and wall painting, glass technology, and bell founding are described.[14] Another early example is Villard de Honnecourt's model – or sketchbook, made around 1220/1230 (Lindgren 2000, 9).[15]

The manuals convey craft knowledge especially through drawings, which are explained through text. The model – or sketchbooks of builders (Baumeister) not only contain information about ground plans, vaults, and longwall systems but also about building cranes and mechanical saws (Hagendorf 1978). Moreover, there are manuscripts on special topics, from the construction of clocks by Giovanni de Dondi († 1389) and Paulus Almanus (15th century) (Lindgren 2000, 9) to recipes for painting art (*Compendium artis pictura*e, early 13th century) (Silvestre 1954) or mining (*Schwazer Bergbuch*, ca. 1550) (Bartels and Bingener 2015).

In addition, there have been writings with a focus on war craft and tactics since the beginning of the 15th century (cf. Leng 2002b).[16] Among the most influential ones in the German-speaking world are Konrad Kyeser's *Bellifortis* (1402-1405)

[11] Cf. the growing database: *Illustrated German-language manuscripts of the middle ages* (only the treaties on military engineering and gunpowder as well as on swordplay and fighting are included yet: https://kdih.badw.de/datenbank/start, Accessed: 29.3.2022).

[12] In the repertory *Historical Sources of the German middle ages* these manuscripts are identified as instructional writings (Lehrschrift), which also include the *Ars dictandi*, musical tracts, mirrors of princes, and treaties on offices (https://geschichtsquellen.badw.de/das-projekt.html, Accessed: 29.3.2022). The historian of technology Lindgren proposes the term «technical encyclopaedia» to account for the peculiarities of the manuscripts among which she includes a conglomerate of topics tending towards technical universality (Lindgren 2000, 9 f.). The term «technical», however, excludes recipe collections from medical, metallurgical and chemical knowledge, which must be counted as craft knowledge. The term «encyclopaedia» then excludes those writings that are not designed for universality.

[13] Also known as *Schedula diversarum artium* (List of various arts).

[14] The identification of the author, who calls himself Theophilus Presbyter, as the monk Roger of Helmarshausen, who was a priest and goldsmith (Freise 1981, 193-200), has been doubted in recent research (Oltrogge 2017; cf. the project of the text's digital edition: https://schedula.uni-koeln.de/index.shtml, Accessed: 29.3.2022).

[15] In addition to these writings, which focus on conveying knowledge about craftsmanship, there are also those that contain technical figures. These drawings (with a focus on building trades) are collected in Nussbaum 1978.

[16] Leng collected more than 170 examples of manuscripts on war handicraft and tactics from 21 libraries (Leng 2002a, 389 f.).

(Leng 2002a, 109-149),[17] the *Feuerwerkbuch von 1420* (Leng 2010a), as well as the writing of the *Anonymous of the Hussite wars* (last third of the 15th century) (Hall 1979). The craft writings of the late middle ages, to which these war craft writings can be counted, usually offer a mixture of quite different fields of craft knowledge.[18] In Italy, writings of this kind were established earlier than in the German-speaking area. The Italian examples show a superior mastery of perspective in their drawings.[19]

3. The Book on Plate Harnesses ('Harnisch-Musterbuch') from Stuttgart

My first case study is based on the so-called Stuttgart *Harnisch-Musterbuch*, which was handed down as part of a collective manuscript together with a partial copy of the Augsburg gunsmith Samuel Zimmermann's († after 1576) *Dialogus*,[20] a well-known and widely distributed literary discussion between a military engineer (Büchsenmeister) and a master of gunpowder (Feuerwerker).[21] The manuscript is incomplete[22] and the stitched layers are not clear.[23] The handwritten entries are subordinate to the drawings.[24] The foliations correspond paleographically to the texts but are continuous. Gamber suggests that 29 leaves have been omitted, the foliation, which has no gaps, must be subordinate and the leaves have been intentionally taken by the scribe, whose motive remains unclear (Gamber 1980, 13).

Technical knowledge is conveyed in the manuscript through 85 drawings and texts supplementing the drawings. The manuscript was written by the etcher Jörg T. Sorg († 1603), who did not directly indicate himself as the scribe. The attribution to

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17 About the same time Munich, Bayerische Staatsbibliothek, *Cgm 600*; cf. Leng 2002b, 205 f. In addition, there are writings that are best known to scholars but less or not at all received by contemporaries: the *Hausbuch* of the Princes of Waldburg Wolfegg (Lindgren 2000, 10).

18 In this context, researchers are discussing whether war craft should be regarded as secret knowledge and therefore not be disseminated as a matter of principle. In view of the great number of manuscripts with war-related content, this point must be put into perspective (cf. Leng 2002a, 396-98 and Jütte 2015, 65-79).

19 Among the best-known craftsmen were Taccola († 1453/58), Lorenzo Ghiberti († 1455), Francesco di Giorgio Martini († 1502), Giovanni Fontana († ca. 1455), Leon Battista Alberti († 1472), and Leonardo da Vinci († 1519) (Lindgren 2000, 10).

20 Stuttgart, Württembergische Landesbibliothek, *Cod. milit. 2° 24*. It is uncertain when the collective manuscript was bound together as its binding is not contemporary. *The Book on Plate Harnesses* (f. 1r-45v; ca. 230 x 345 mm) has a distinctly different format than the *Dialogus* (f. 46-79r; ca. 205 x 330 mm), which is provisionally dated after 1600 due to watermarks on the paper (Irtenkauf 1980, 9).

21 Another text about fire and its benefits is assigned to Samuel Zimmermann: *Pyromachia;* cf. Leng 2002a, 353-58 and Leng 2010b.

22 Irtenkauf 1980, 9. The entry f. 42r is fragmentary; in addition, entries for the years 1555, 1560-1562 are probably missing. Irtenkauf calculates that 29 leaves must have been omitted (Gamber 1980, 13).

23 For detailed information cf. Gamber 1980, 11-13.

24 Cf. footnote 29; the coats of arms also adapt to the templates (Harnisch-Musterbuch, f. 14v, 19r, 21v, 30r, 33v, 38r, or 41r).

an etcher, however, results from the illustrations' captions.[25] Some of the harnesses drawn in the codex have survived as objects and some bear not only the signature of the plater assigned in the manuscript but also the signature of the etcher Sorg.[26] In a letter to the King Gustav I of Sweden († 1560) from 1559, Jörg T. Sorg is described as a painter and etcher of harnesses («maller vnd etzer auffs harnissch») and can be found between other craftsmen involved in the production of harnesses (platers and polishers). The letter bears Jörg (= Georg) Sorg's seal: A parchment knife in a shield above the initials GTS. It contains information about negotiations between the craftsmen and the court. The Swedish king wanted to employ Sorg and the other masters at his court (Gamber-Becher 1980, 26).[27] Sorg was thus firmly connected with the other professions. Furthermore, the letter is written on paper with a pressed-through border pattern. This border pattern is identical to the pattern on the harness for Vratislav von Pernstein († 1582), which was produced by the Augsburg plater Wolf Neumair († 1563) and whose pattern had been made by the manuscript's scribe (Harnisch-Musterbuch, f. 33r-34r). The letter again depicts a collaboration between the plater Wolf Neumair and the etcher Jörg Sorg (Gamber-Becher 1980, 26).

Jörg T. Sorg's father, named Jörg Sorg, was a city painter of Augsburg and his mother Catharina († 1553) a daughter of Kolman Helmschmid († 1532). In 1548, Jörg T. Sorg was granted the right to paint in Augsburg by the guild (Gamber 1980, 17). His drawings have been dated from 1548 to 1563 (Gamber 1980, 11). Gamber proposes to narrow the time further based on the following entry: «Item, this armour made for battle I have etched for Wolf Neumair, belongs to the Lord Vratislav of Pernstein on Pardubice, councillor and chamberlain of the Roman emperor. 1556».[28] Vratislav of Pernstein († 1582) was a councillor (Geheimer Rat) of King Maximilian II, who had been elected king in 1562 and crowned emperor in 1564. The entry about Vratislav von Pernstein must have therefore been made between 1562 and 1564 (Gamber 1980, 13 f.). Thus, it must be noted that the plate harness was made at least six years before the inscription was written down. The illustration that preceded the inscription must therefore have been written down after 1556 and before 1564.[29]

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[25] E.g. «Jtem disen fu̔ss kyris hab ich dem Matheus Frawen breÿ̆s gheetz gehertt dem donn Kaspar de Qu̔inarach 1549» (Item, I have etched this armour for the fight on foot to Matthäus Frauenpreiss, belongs to Don Kaspar de Quiñones 1549) (Harnisch-Musterbuch, f. 3r).

[26] Boeheim first suggests the attribution to the etcher Sorg in 1891 (Boeheim 1893, 207); in addition, the Sorgs' family coat of arms is depicted several times in the codex (Harnisch-Musterbuch, f. 9v and 10r). A cross (†) on f. 27r correlates with the year of his mother's death (Gamber-Becher 1980, 27; Harnisch-Musterbuch, f. 27v).

[27] Seal image: Gamber-Becher 1980, 27. Letter edited by Meyerson 1939, 215 f. quotation on page 216.

[28] «Jttem dissen kempff kÿris hab ich dem Wolff Neÿmer geezt gehert dem hern Vrattislaŭs von Bernston aŭff Parduŭwizt. Ro kÿ̈mt ratt vnd camerer. 1556» (Harnisch-Musterbuch, f. 33r).

[29] The inscription considers the helmet's shape; likewise: Harnisch-Musterbuch, f. 3r, 6v, 21v, 25r or 26v; differently with the lances, which were drawn over the writing (f. 2r-v, 4v. 6r. 7r, 8r, 13r, 18r,

The manuscript's direct addressee is unknown. It is also unknown how the manuscript came into the Duchy of Württemberg's possession. However, the manuscript was certainly addressed to potential buyers of harnesses. In the court accounts of emperor Maximilian II it is written on May 28, 1564: «Georg Sorg, painter at Augsburg, receives for several drawings of harnesses made for Emperor Maximilian (II), 4 gulden by his own hand» (Gamber-Becher 1980, 27). Although it is highly unlikely that the Stuttgart codex contained these drawings of harnesses, this entry in the court accounts nevertheless shows that drawings by Sorg circulated even at the imperial court.

The watermark analysis of the manuscript, which was executed by the well-known watermark researcher Gerhard Piccard in the course of the edition, gives the following picture: F. 1-41 are of the same watermark which, according to Piccard, can be retraced to Augsburg between 1544 and 1551 (Gamber 1980, 11).[30] F. 44 has a different watermark which, following Piccard, is attested in Urach in 1561 (Irtenkauf 1980, 10; Briquet 1923).[31] This watermark can still be found in other manuscripts about military engineering. On the one hand, the large Tetschen manuscript (†) with armour drawings probably contained this watermark.[32] On the other hand, there is a parallel to a manuscript of Samuel Zimmermann's *Dialogus*, which also bears the same watermark (Leng 2010b). Zimmermann's *Dialogus* appears here for the second time. A coincidence that can only be explained by the thematic proximity. The codicological examination, however, appoints the manuscript not only into the context of military engineering writings but also to Augsburg (Irtenkauf 1980, 10). Both classifications agree with the content. Furthermore, it is no coincidence that such a handwriting was created in Augsburg as the city was considered a leading hub for this product in the 16th century. For further analysis it is necessary to look at the product, the manufacturing profession, and the buyers.

Plate armour with movable arms and legs was developed in Italy in the second half of the 14th century with the city of Milan being the technological leader (DeVries and Smith 2007, 172-83). Since the middle of the 15th century, plate armour lost its initially great protective function in the face of new weapon technologies and war tactics. Even though it was almost useless in active warfare by the middle of the 16th century, the plate armour retained its function as an object of

20r, 21r, 23r, 27v, 28r or 29r). This finding indicates a multi-part work process: Possibly the people were first prepared as a template, then the inscription was added and only afterwards the design of the armour, the coats of arms and the lances or swords.

[30] In the watermark database, which is based on Piccard's collection, the watermark has not been included. However, it can be found in Briquet (Briquet 1923), where it refers to Vienna 1563 and 1565-1573, Hustopeče 1563, Augsburg 1566, Ljubljana 1568-1570, and Bratislava 1576 (http://briquet-online.at/2117, Accessed: 28.03.2022; Briquet 1923).

[31] The assignment to Urach cannot be traced. Briquet mentioned Praha 1537-1554, Augsburg 1545-1565, Stuttgart 1555, and Landsberg am Lech 1561-1632 (http://briquet-online.at/1243, Accessed: 28.03.2022).

[32] Former library Thun-Hohenstein at Tetschen, Bohemia, Codex a/2. As far as it is at all possible to make statements about this manuscript, which was lost during the Second World War, there are also parallels in content here.

representation. Hence, the development of its practical use in combat and its representative function can be regarded as contrary. The design of the plate harness showed the social position and the social rank. Furthermore, plate armour was an essential part of knightly tournament fights (Gamber 1980, 14). The plate armour had evolved «from the first warlike utilitarian piece of the nobility to the exclusive status costume and multi-piece luxurious sports equipment» (Gamber 1980, 14).

Plating is a highly specialized craft based on experience and extensive knowledge of materials. The harness had to fit, which meant adapting to the wearer's physique, the joints had to be movable and, depending on their function, withstand physical manipulation. In addition, the appearance of the plate armour should correspond to the current fashion. Four to six masters were involved in the manufacturing process of a single product: Platers worked on the forging, polishers were responsible for smoothing and straightening, girdlers for strapping, upholsterers for the silk lining. Optionally, etchers and gilders were involved to decorate the harnesses (Gamber 1980, 15 f.).

In the empire, the platers of the cities of Augsburg, Innsbruck, and Nuremberg emerged as the technological leaders, with Italian craftsmen being superior in the production of embossed ceremonial armour. Augsburg specialized in luxurious work, whereas Nuremberg focalized mass production. After 1620, the demand for luxury armour ceased. During the period of the emperors Frederick III, Maximilian I, and Charles V, it was seemly for the German and Spanish courts to have their products manufactured in Augsburg, where the emperors bought as well. After 1560, Augsburg lost this supremacy as King Philip II of Spain turned to Landshut's plater workshops and Maximilian II followed. In addition, Milan regained importance (Gamber 1980, 15-17). In this time of Augsburg's loss of supremacy, *The Book on Plate Harnesses* was created in Augsburg, which recorded the heyday of the formerly exclusive court supplier of magnificent plate armour.

This thesis is supported by an analysis of the content. The manuscript lists all the important Augsburg masters with whom the etcher Sorg worked as well as the important patrons, with the harnesses standing in the centre. The drawings of the armour are uniform in their layout, which indicates the utilization of a template. Moreover, a preliminary drawing is not visible and the drawings were supplemented by colourful watercolour painting. Metal parts were painted in blue wash or black, gilded parts of the graphic (etched) decoration in yellow, ground stripes in brown-green. The coats of arms, lances, costume parts, and patterns of the command staffs are colourful; stronger paintings with opaque colours were probably applied later (Gamber 1980, 13).

The armour demonstrates the wealth of variations that the Augsburg platers were able to produce in combination with the other crafts. Not only the craftsmanship and artistic design become apparent in the manuscript but also the knowledge of how extensive an armour was and which parts belonged to it. Written numbers on the bottom of the pages refer to the number of armour parts; they can be understood as the scope of supply (Gamber 1980, 14).[33] The number of pieces of armour can be six, if the armour consists only of helmet, bevor / gorget, two pauldrons, cuirass, and backplate, or twelve: helmet, bevor / gorget, cuirass, backplate, two pauldrons, two armlets, two gauntlets, and two saddle-plates. Several figurines often represent one delivery, which is why the numbers of the delivery scope are correspondingly large. For example, the order for Ludwig Ungnad of Weißenwolff, Freiherr of Sonnegg († 1584) consists of 80 pieces (Gamber 1980, 14; Hengerer 2012, 1533-5). All in all, the figures give, according to Gamber, precise information on how many parts a harness consisted of, which was important knowledge for producers and buyers (Gamber 1980, 24).

> This shows that around the middle of the 16th century, the harness was already subject to a standardization of its technical composition, which had developed in the courtly circles and was equally binding for the nobleman as well as the plater (Gamber 1980, 24).

Gamber assumes that the specified scope of supply was important to the etcher, as it would have served as proof of his activity (Gamber 1980, 25). In my view, the chosen recording method, namely written word and numbers in combination with images, is too elaborate for an order book. The knowledge conveyed there does not refer solely to clients owing payment to the etcher. For that knowledge you need no images and an order book's most important point is missing: The costs for the objects and the work. In addition, the platers with whom Sorg worked are named. They were all Augsburg master craftsmen whose fame was known far beyond the city and some of whose work had been handed down to us to this day (Gamber-Becher 1980, 28-45).

Gamber agrees that Maximilian II is a key figure among the clients (Gamber 1980). Although he himself is listed merely once as a client (Fig. 2), his closest circle also appears as well as the Spanish buyers (and the Italian ones), who were connected to him through his wife (belonging to her or Philip II's court). Clients from the European nobility can be found as well as citizens from Augsburg, the latter with a different helmet shape (Fig. 1-2).

The clients are mentioned in the inscriptions and their coats of arms are placed prominently on the side of each figurine (Fig. 1-2); the coat of arms attached to Maximilian II's plate armour for foot combat (Fig. 2) was revised. The one originally placed there was pasted over with a piece of paper on which the large archducal coat of arms, including Bohemia-Hungary's royal coat of arms, had been painted. When and by whom the updating was done is unclear. Gamber sees this as evidence that the harness was still in production at the time of Maximilian's elevation to King of Bohemia (1562) and that the coat of arms therefore had to be changed

[33] The word «rechnung» on Harnisch-Musterbuch, f. 5v marks the numbers and signs as representation for piece numbers.

(Gamber 1980, 17). The inscription indicates 1549 as the year of production. In my opinion, the coat of arms' correction should be seen independently of the armour's production. The drawings in the manuscript were made after the armour was produced anyway. The coat of arms' correction only shows that the manuscript was started before 1562. Since its last dating is from 1563, the corrector can be identical with the scribe. Sorg updated the manuscript and added the more prestigious coat of arms of the King of Bohemia.

Fig. 1. **Harness of a bourgeois**

Fig. 2. **Harness of Maximilian II**

In this codex, knowledge is transported in different ways. The artistry of the Augsburg harnesses is conveyed and at the same time Sorg demonstrates what he can create through the drawings.[34] The illustrated manuscript offers the possibility

[34] In retrospect, the fashions and their change in the years 1548 to 1563 can be seen (Gamber 1980, 25).

for anyone who had access to get an overview of what the Augsburg harness makers were able to produce, what forms and finishes were possible and current, and who decided on which form. The manuscript thus not only conveys knowledge about the product and the craftsmen's skills but also which craftsman was able to produce which products or with whom an etcher worked together. Furthermore, it becomes apparent for whom harnesses were produced and for whom a special harness form and decoration was created. Thus, the manuscript could assist in the decision after which model the own palate armour could be made and hence, in who's shadow one wanted to place oneself. This indicates that the products were not only shown and advertised in a certain way, but also that social knowledge was transported. Therefore, the inclusion in a social group, in which the potential buyer could also place himself by purchasing the plate armour in the latest pattern, was communicated. But why was this knowledge recorded at all? Is it «only» social information or can economic interests be suspected behind it? *The Book on Plate Harnesses* can be read as a kind of catalogue that advertised the Augsburg harness makers and etchers. The manuscript's time of writing offers information about the Causa Scribendi, which wrote and drew a representative of the former market leaders of a luxury product. The knowledge conveyed through the manuscript should recruit other clients. Last but not least, Jörg T. Sorg also records knowledge for himself. In this way, the book can also be read as a reminder, a memorial, for what he (and the Augsburg harness makers) could produce.

4. Christoph Sesselschreiber's Book of Casting

My second case study is based on a manuscript by the bell founder Christoph Sesselschreiber, entitled *Of bell and artillery foundry, military engineering, gunpowder processing, fireworks, hoisting and crushing equipment, water and well works*.[35] Using the example of bell casting, which is a highly complex craft, the problem of solely orally transmitted knowledge will be briefly explained. In the 15th and 16th centuries, bell-casting centres developed in a number of cities, among them Salzburg (Kral 2020, 443). Some of the Salzburg bell founders were so renowned that they received orders from beyond their region, e.g., the Salzburg founder Jörg Gloppitscher († 1480). Among other objects, he cast the large bell for Wasserburg am Inn.[36] Jörg Gloppitscher had no direct successor, his foundry was sold several times, and none of the owners could reach to his level. Apparently, Gloppitscher's templates were sold separately. In addition, the bells from his successors' foundry (esp. Josef Erhart, a founder who obtained the Salzburg citizenship as a goldsmith) were less elaborately decorated and showed less variance in their inscriptions, which were, however, inspired by Gloppitscher's (Kral speaks of imitation). The construction of

[35] Von Glocken- und Stuckgiesserei, Büchsenmeisterei, Pulverbereitung, Feuerwerk, Heb- und Brechzeug, Wasser- und Brunnwerken (Munich, Bayerische Staatsbibliothek, *Cgm 973*).

[36] Called «the Salzburgerin», weight 4500 kg (Kral 2020, 443 f. and 454, annot. 2-3).

the bell also did not reach its predecessor, which affected its musical quality. In addition, casting defects are often found in the bells such as rough surfaces and gas inclusions (Kral 2020, 444-46). Hence, if a workshop was not continued, the knowledge was lost with the master. Conversely, this was different with knowledge conveyed through written manuscripts.

Christoph Sesselschreiber, the writer of the manual about bell founding, was the son of the Munich painter Gilg (Ägidius) Sesselschreiber, who had been a painter at the court of Maximilian I († 1519) since 1502. In 1508 Gilg Sesselschreiber was commissioned to lead the casting work for Maximilian's tomb in Innsbruck.[37] He was put in charge of the princely foundry in Mühlau near Innsbruck with staff and employees, including the bell founder Peter Löffler. The foundryman's expertise was certainly extremely important for Gilg, who as a painter had no experience with casting. Another painter, two carvers, two founders, a brazier, and a blacksmith worked under his direction (Hartig 1927, 279; Egg 1961, 54; 62).

It is likely that Gilg prepared drawings that served as the basis for the cast figures.[38] The idea that knowledge of craftsmanship, in this case of bronze casting, was written down and drawn on paper was therefore not new to Christoph Sesselschreiber. He had apparently acquired sufficient knowledge of bronze casting in the foundry run by his father to produce his own castings. Thus, in 1519 he cast the bell of the Salzburg City Hall and in 1521 the bell for Arnsdorf (Salzburg). Sesselschreiber was presumably active in Salzburg between 1518 and 1521 (Egg 1961, 62; Kral 2020, 451). Afterwards, Christoph possibly went to Munich. It is uncertain whether he had a permanent employment relationship with Duke Wilhelm IV of Bavaria († 1550) as the court accounts have survived only sporadically and the tax books list a painter Christoph in 1525 and 1526 but without a surname (Hartig 1927, 280; Leng 2002a, 369).[39] Moreover, journeys to Bavaria, Austria, Salzburg, and Innsbruck are documented. It is unknown whether Christoph had a fixed location where he executed the commissioned work or whether he should be assessed as a traveling bell and gun founder (Leithe-Jasper and Gürtler 1996, 88; Leng 2002a, 369).[40]

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[37] For details on Gilg and the events surrounding the production of the figures that led to his temporary imprisonment cf. Hartig 1927, 278-82; Leng 2002a, 369; Egg 1961, 62; still fundamental Schönherr 1890.

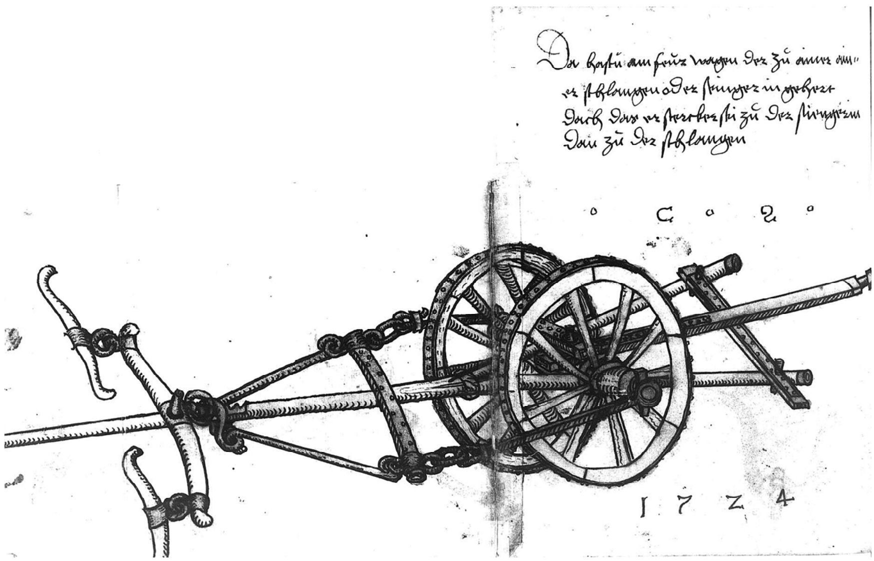
[38] Schönherr 1890, 170-6 assumes that Vienna, Österreichische Nationalbibliothek, *Cod. 8329* was made by Gilg Sesselschreiber. According to the library, the drawings were made by the court painter Jörg Kölderer and were based on Gilg Sesselschreiber's drawings and the bronze casts.

[39] Following Boeheim 1897, 59 Sesselschreiber stood in the duke's service, but again Boeheim gives no clues as to where he obtained this information.

[40] According to Egg, the described gun types indicate travel (Egg 1961, 63). The coats of arms painted in the manuscript show us the buyers of Christoph's objects: Coats of arms of Bavaria, Austria, Salzburg (including the coat of arms of Archbishop Leonhard von Keutschach, who died in 1519), Innsbruck, Nuremberg, Württemberg, Augsburg, and Hungary.

The book examined here was written by Sesselschreiber in 1524 and was in the possession of Duke William IV, as evidenced by a handwritten note by his brother Duke Louis X († 1545).[41] The manuscript's attribution to Sesselschreiber as its writer is quite simple; he constantly refers to himself in the manuscript (e.g., Sesselschreiber, f. 1r, 6v, 7v, and 8r). The manuscript consists of 158 leaves bound in parchment.[42] Sesselschreiber utilizes both texts and drawings to convey his knowledge. It is striking that in his writing he alternates between the usual cursive and a font consisting of capital letters enriched with smaller figures, acorns, stars, bells, and so on. The letters D, S, and N are mirror-inverted throughout.[43] The illustrations are made with watercolour technique. According to Boeheim, the manuscript is «awkward and incorrect, but sometimes vivid and mostly understandable» (Boeheim 1897, 60).

Fig. 3. **Chariot for a cannon**



Because the manuscript has not been edited, the content's analysis must be more detailed. The book can be divided into several parts as already the title preserved in the library shows. The first part covers the foundry of bells (casting plac-

[41] On the back cover of the codex is written: Return to brother William, acted on 14.01.1542 («Brueder hertzog Wilhelm wider zuzu stellen, actu(m) den 14 tag Jenner Anno 1542»).

[42] In quarto format (160 mm x 215 mm); 145 of these leaves are foliated.

[43] Boeheim sees in it a youthful and unskilled writer (Boeheim 1897, 60). By using the cursive Sesselschreiber never had such problems.

es, casting tools, cross-section of a bell, table with wall thicknesses); knowledge is conveyed both in pictures and as text (Fig. 3).[44]

The foundry section also covers gun foundry, which includes the crafting of guns, pipes, and bullets (on gun-powder artillery cf. DeVries and Smith 2007, 195-202).[45] The next part describes the operation of the guns using tools (such as setting scales). Furthermore, this part is interspersed with coats of arms (Sesselschreiber, f. 23r-42r). «Here he stands on the ground of the very own study and experience, and resolutely advances his colleagues» (Boeheim 1897, 61).[46] According to Boeheim, «everything proves the capable expert and serious thinker. In individual cases, he becomes an ingenious inventor again» (Boeheim 1897, 62). Sesselschreiber was particularly significant as a designer of gun mounts (frames for cannons) (Boeheim 1897, 62). Thus, the illustrations of guns on racks also occupy a significant place (Fig. 3).[47] You can read there: «There you have a fire chariot, which belongs to a culverin or a long kartouwe (Singerin), but it (fits) better with the long kartouwe then with the culverin. C(hristoph) S(esselschreiber). 1524».[48] Next, techniques for calculating flight altitude and range and necessary instruments are treated (Boeheim 1897, 62).

The following topics are lifting and crane devices, some of them very complex, which a bell and gun founder urgently needed for his work to transport bells and guns or to install bells in towers.[49] Bell casting in the 15th century had reached the point where musically excellent bells could be cast, which could also be very large (several thousand kilograms) and still be placed in the towers (Kral 2020, 443). In this part of the codex, knowledge is conveyed not only on a textual and pictorial level but also on a haptic level. Sesselschreiber depicts complex hoisting devices consisting of multiple pulleys and ropes with the aid of threads. Instead of drawing

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[44] Sesselschreiber, f. 1r-2r: on furnaces, shape, and casting of bells and their sound; f. 3r-11r: on hanging of bells, on weights and measures (in addition, repeatedly page-long instructions) (Boeheim 1897, 60 assumes that it is a copy of an older text).

[45] Sesselschreiber, f. 15r: culverin Nuremberg type; f. 15v: Bavarian style; f. 16r-v: falconet; f. 17r-v: falcon; f. 18r: long kartouwe (Singerin); f. 18v: medium size cannon (Scharfmetze); f. 19r-21r: several versions of cannon balls.

[46] In contrast Egg 1961, 63: «The book itself is a late descendant of the fireworks books rather than a manual of the new artillery created by Emperor Maximilian and, in contrast to Strasbourg, for example, suggests that gunnery in Bavaria before 1525 was more conservative than progressive»; cf. Leng 2002a, 369 f.

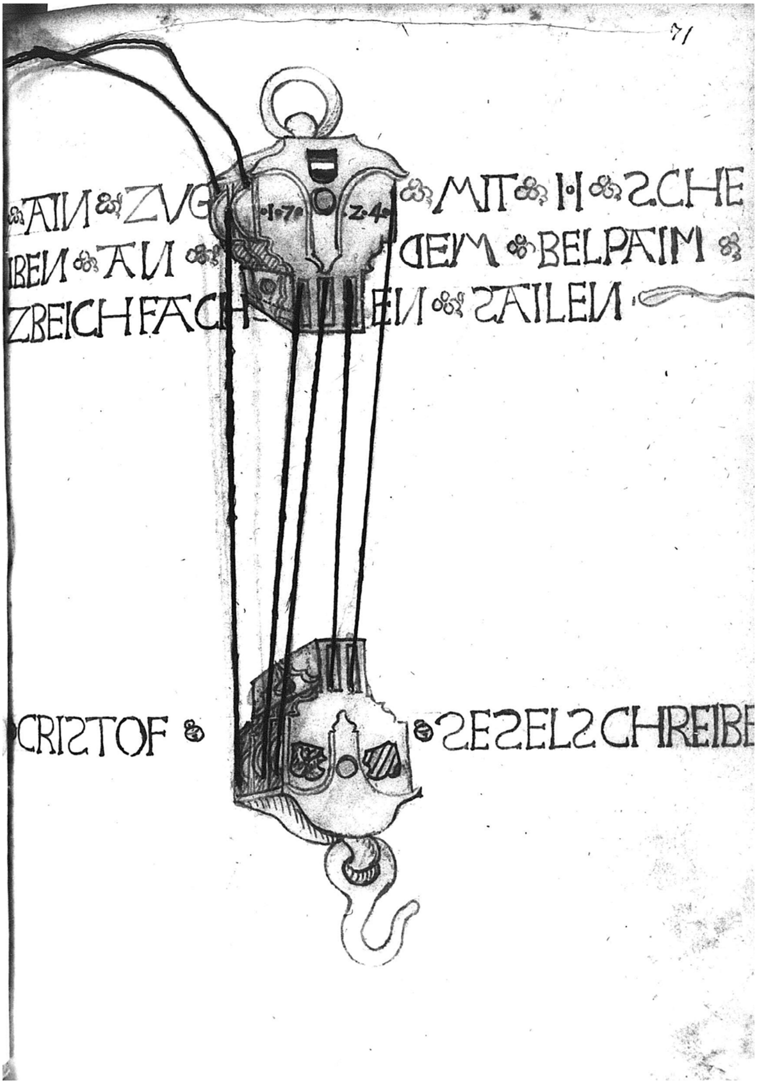
[47] Sesselschreiber, f. 42v-43r: gun on a stand; f. 43v-44r: artillery on mount (for the size of the figure a larger sheet was added; cf. Fig. 3: Sesselschreiber, f. 44v); f. 44r: limber; f. 45r: wheeled cart for use in a wagon castle; f. 45v: Bavarian field artillery (all on extended sheets).

[48] «Da hastuʿ ain feuʿr wagen der zuʿ ainer schlangen oder seingerin gehert dach das er stercker sei zuʿ der siengerin dan zuʿ der schlangen. C.S. 1524». (Sesselschreiber, f. 44v).

[49] Sesselschreiber, f. 60r-72v: hoisting device; the ropes were partly not drawn but threads were punched through the manuscript (69r-72v) in between coats of arms; on hoisting devices drawn in manuscripts cf. Scaglia 1966.

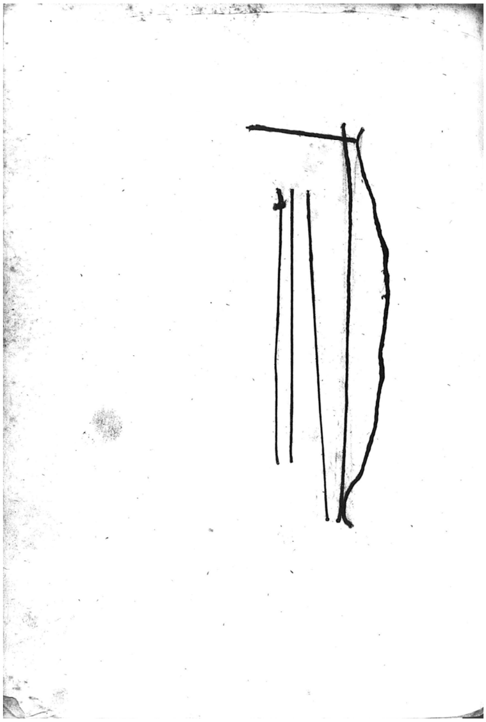
ropes, he punched threads through the codex (Fig. 4-5). The text says: «a hoisting device with eleven pulleys on which hang two ropes. Cristof Seselschreiber».[50]

Fig. 4. **Hoisting device**



[50] «Ain zug mit 11 scheiben an dem belpaim zbeichfachen sailen. Cristof Seselschreiber» (Sesselschreiber, f. 71r).

Fig. 5. **Threads punched through the codex**



The following two parts, consisting of recipes for powder and military and civilian fireworks,[51] siege weapons,[52] and divers,[53] certainly go back to other written sources. Sesselschreiber's manuscript is strongly linked to other treaties on military engineering and it appears that a part of these manuscripts refers to conventions of presentation (Friedrich and Krusenbaum-Verheugen 2021).

Sesselschreiber describes the contemporary artillery but not the new developments recognizable since 1520. Boeheim draws attention to the fact that Sesselschreiber referrers to the old, known fireworks books. However, he do not hand down the old, incomprehensible recipes but rather cited «improvements

[51] Sesselschreiber, f. 74r: list of materials; f. 74v-78v and f. 80r-84v: recipes for powder and (military) fireworks; f. 87r-90v: arrows and powder for arrows; f. 91v-105v: recipes; f. 107r-123r: dealing with sulphur and saltpetre.

[52] Sesselschreiber, f. 123v-132v: siege weapons; Sesselschreiber, f. 126r has similarities with Munich, Bayerische Staatsbibliothek, *Clm 197, I,* f. 12v (cf. Hall 1979, 40 f).

[53] Sesselschreiber, f. 135v-140r. The illustrations show similarities with Munich, Bayerische Staatsbibliothek, *Clm 197, I*, f. 12v, 13r, and 14r and *Clm 30150*, fol. 78v-80r (cf. Hall 1979, 40 f.; Egg 1961, 63); they can probably be found in other manuscripts as well. Hartig assumes Robertus Valturius († 1475): *De re militari* or Vegetius (both printed) as models for the technical drawings (Hartig 1927, 283 f.). Leng added to this list books from the circle of Johannes Formschneider († after 1470) and the *Feuerwerkbuch von 1420* (Leng 2002a, 370).

based on his own invention and testing», which are, however, explained incomprehensibly (Boeheim 1897, 60). In addition, he highlights the fact that he was recording new technology several times in the manuscript (Sesselschreiber, f. 65v-66v and 68v-70r).

Independent is the last part of the manuscript, which contains knowledge about the construction of water heaters and bathhouses, waterworks for fountains, as well as decorative fountains.[54] The book is particularly interesting for the casting of fountains and bells, which Theophilus Presbyter wrote about before Sesselschreiber (12th century) (Kral 2020, 451). Especially the detailed calculations of the bell construction and the new lifting process with vertical axis are to be highlighted. This new lifting method made it easier to hoist products weighing several tons into the casting pit and is still in use today (Kral 2020, 452).

The constantly recurring coats of arms of the patrons, which also await a more detailed analysis, do not indicate the manuscript's patrons,[55] but provide information about the products made by Sesselschreiber. This puts the manuscript into a clear relationship with *The Book on Plate Harnesses* (Leng 2002a, 369). These parts, according to Leng, should be read as a «memorial book» about the things cast by him (Leng 2002a, 370). In my opinion, the interpretation as a «memorial book» does not go far enough; the proximity to *The Book on Plate Harnesses* rather shows that knowledge is also stored for potential future employers.[56] Sesselschreiber can thus show his repertoire and announce himself. He describes not only what he can theoretically produce but what he has already created.[57] No one could learn founding bells, fountains or guns, and constructing scaffolds, siege towers or grinders directly from the manuscript; however, if you were already able to found and build things, then you could imitate the techniques provided in the manuscript. The manuscript addresses master bell founders who could adapt technology and their buyers who could chose a gun, fountain or siege tower they liked.

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[54] Sesselschreiber, f. 141r-142v: water heater and bathroom; f. 143r-153v: waterworks for wells; on fountains cf. Magnusson 2001, 103-9 and on hydraulic technology Magnusson 2001, 169.

[55] Egg 1961, 63 assumes that the book was dedicated to Wolfgang Hofer von Urfahrn, the son of the important Schwaz mining entrepreneur Virgil Hofer († 1496). Egg describes him as a patron who brought Sesselschreiber into the Lower Bavarian service. This conclusion is based on the erroneous assumption that the repeated drawings of Hofer's coat of arms indicated patronage.

[56] Leng also softens the attribution «memorial book» and draws attention to the fact that it «could have served as a presentation to his patron» (Leng 2002a, 371). In addition, Leng sees it as an effort «to rehabilitate himself as a gun and bell founder, perhaps to acquire new orders, and at the same time to prove his abilities […]» (Leng 2002a, 370).

[57] For example, two fountain drawings are provided with locations. In the drawing of a fountain with a statue of the Lorelei it is written: «stet auf der Maczen» (Sesselschreiber, f. 149v. Burg Matzen im Unterinntal; Hartig 1927, 284) and in the drawing of a fountain with Freising coat of arms: «sett in Freiszing» (Sesselschreiber, f. 150r; Hartig 1927, 284).

5. Conclusions

The case studies show that craftsmen, masters of their trade, transmitted knowledge in manuscripts. Those manuscripts are multifunctional and, besides a whole range of functions, serve to transfer useful knowledge for economic purposes. They convey useful knowledge in written, pictorial, and partly haptic form. Moreover, they address the knowledge to the future and to the craftsmen of their own craft, who partly received the writings and compiled them into their own records. The countless manuscripts bearing this knowledge demonstrate the craftsmen's interest in the latest (military) technology. Current fashions and innovations are conveyed, but neither the writings nor the images do provide the know-how on how to manufacture the products. The transmission of this knowledge remained in the workshop and bound to the human being; it was not passed on in manuscripts. It remains practical and oral to this day. The construction drawings and concept collections show what is possible and conceivable, but they do not convey the knowledge of how the products could be made.

The fact that not all objects could be realized might be obvious with regard to the divers, but the writers mark the already realized objects with the buyers' coats of arms. This also explains the supposed lack of knowledge, which Reith describes as empty spaces that have to be filled with knowledge acquired in the workshops (Leng 2004, 97; Reith 2005, 352-3). A plater, however, can very well recognise how many parts an armour has, which parts are currently used for which armour, and how the armour is cut from *The Book on Plate Harnesses*; the etching painter recognises the patterns that are in fashion. A bell founder can read the measurements and utilize them or reconstruct the beam construction for his own lifting gear. For better illustration, the threads for the tackle are punched into the manuscript as examples. However, an unskilled person cannot do anything with them. Today, construction drawings are standardised and much more complex, but again, the amateur can do nothing with them. What is conveyed are new techniques and innovations within one's own craft; Sesselschreiber repeatedly draws attention to the fact that he reflects new techniques. In this way, complex technologies can be communicated. This aspect is more evident in Sesselschreiber's manuscript, which contains a mixture of conventional, old familiar knowledge and new knowledge. The innovation, however, did not take place in the manuscript but in the workshop. Sesselschreiber's new technologies are usually marked with coats of arms, i.e., they were actually built. Sesselschreiber thus ensures that he will be able to reproduce the complex constructions even years later. Therefore, the manuscript served as a memorial device. This article shows that writing is equally used to disseminate useful and valuable knowledge beyond the individual and thus contributes to the question of artisan writing.

At the same time, a potential client's attention can be drawn to the products, which are not display goods that were first made and then sold. Contrary, all these products were very expensive. The manuscripts advertise goods which cannot be shown in a shop. Thus, these manuscripts served to increase the sales of the products as the knowledge about them and their appearance had to leave the narrow framework of the craft in order to sell them. These results can be applied to the question of the sale of luxury goods. In the case of *The Book on Plate Harnesses*, it should be added that the writer is writing against the crafts' decline in Augsburg. He demonstrates the art of plate harnesses in order to help the city's craftsmen back to the top. The book can therefore be seen as a fight against economic decline. This shows that writing was used as a way of regaining economic significance. This result is certainly interesting for the questions about methods to strengthen one's own business.

It is also interesting to examine who could access the military objects and the knowledge about them and whether new technologies were kept under secrecy in order to have a strategic advantage in wars. More research is needed here. In addition, the objects' production involved several craftsmen working together. This applies to the crafting of harnesses as well as bells, fountains, and war machines. The etcher also displays samples of his work by inserting his patterns into the drawings.

The coats of arms and names in the manuscripts indicate that individual products have already been made and tested. Moreover, the client can place himself in a line of prestigious former customers by buying the products. This is how advertising still works today (e.g. the British court suppliers).[58] The knowledge that is imparted is multi-layered; in addition to craft knowledge, there is social and cultural knowledge that craftsmen preserved via manuscripts. But it is the everyday skills that cannot be conveyed through books.

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Raffaele Danna

The spread of Hindu-Arabic numerals among practitioners in Italy and England (13^{th}-16^{th} c.): two moments of a European innovation cycle?

Introduction

As part of the debate on the 'great divergence', a growing stream of literature has stressed the role of culture and of 'useful knowledge' in the advent of modern economic growth (Mokyr 2005; 2011; 2017; Clark 2007; Pomeranz 2000). In parallel, a recent debate on the long-run determinants of the industrial revolution has brought forward the idea of a 'little divergence' of the economies of the Low Countries and England in the pre-modern period. This literature shows that these northern European areas experienced a persistent growth in terms of real wages, GDP per capita, urbanisation and agricultural productivity since the late middle ages, setting them on a trajectory that culminated with the industrial revolution (Malinowski and van Zanden 2017; Broadberry et al. 2015; Álvarez-Nogal and Escosura 2013; van Zanden and van Leeuwen 2012; Allen 2000; 2001; van Zanden 1999; De Vries 1984). A debate ensued investigating the determinants of economic growth in the pre-modern period. A number of hypotheses emerged, with scholars first highlighting a relevant role of structural factors, such as international trade and institutional change (Acemoglu, Johnson, and Robinson 2005; Allen 2003) and, more recently, the role of 'human capital' and of access to information (De Pleijt and van Zanden 2016; Dittmar 2011; Van Zanden 2009). This paper contributes to this literature by focussing on the adoption of Hindu-Arabic numerals (0, 1, 2, 3, 4, 5, 6, 7, 8, 9) in European commercial practices. By providing a mathematical tool which made it possible to handle rational numbers more effectively than Roman numerals, Hindu-Arabic numerals arguably played a key role in the development of the innovations of the commercial revolution of the 13^{th} century, and in their diffusion.

It has been argued that it is possible to identify a continuous spread of Hindu-Arabic numerals from the commercial revolution of the 13^{th} century to the little divergence of England and the Low Countries (Danna 2022; 2021). In this paper, I expand on this hypothesis by investigating the diffusion of advanced commercial practices and of other forms of practical knowledge in the initial and final contexts of this process. As can be seen from Table 1, data on the publication of practical arithmetic manuals show that late medieval Italy and early modern England were, respectively, the early mover and the late adopter of Hindu-Arabic numerals in vernacular contexts. In this paper, I expand on the complex social and economic fac-

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Referee List (DOI 10.36253/fup_referee_list)
FUP Best Practice in Scholarly Publishing (DOI 10.36253/fup_best_practice)

Raffaele Danna, *The spread of Hindu-Arabic numerals among practitioners in Italy and England (13^{th}-16^{th} c.): two moments of a European innovation cycle?*, © Author(s), CC BY 4.0, DOI 10.36253/979-12-215-0092-9.06, in Giampiero Nigro (edited by), *L'economia della conoscenza: innovazione, produttività e crescita economica nei secoli XIII-XVIII / The knowledge economy: innovation, productivity and economic growth, 13^{th} to 18^{th} century*, pp. 59-87, 2023, published by Firenze University Press, ISBN 979-12-215-0092-9, DOI 10.36253/979-12-215-0092-9

tors that help to explain this remarkable distance in time between the adoption of this mathematics in Italy and England. Moreover, this analysis makes it possible to identify a number of significant parallels between the two contexts, showing how technical change (in this case, change in commercial practices) was associated with social and cultural changes.

I will first focus on the innovations of the commercial revolution of the 13th century, which led to the emergence of new markets and of new forms of enterprise. These structural changes corresponded with the emergence of new institutions, which were developed to bring to scale the innovations of the commercial revolution. Thanks to its increasing social diffusion, the practical knowledge underpinning these new economic practices started to spill over into fields beyond commerce, contributing to knock-on effects in new social and institutional contexts, and thereby contributing to influencing a broader set of fields and practices. As we will see, it is possible to identify a similar sequence of events in both late medieval Italy and in early modern England. By focussing on the initial and final phases of the diffusion of Hindu-Arabic numerals in vernacular contexts, it is possible to observe the continuities that characterised the European spread of this practical mathematics.

Tab. 1. **Publication of practical arithmetic manuals in Italy, England, and Europe**

	Italy	England	Europe TOTAL	% Italy/Total	% England/Total
1250-1300	2		2	100	
1301-1350	19		22	86	
1351-1400	24		27	89	
1401-1450	60		63	95	
1451-1500	133		163	82	
1501-1550	119	9	366	33	2
1551-1600	126	46	645	20	7

Source: Danna 2022.

In highlighting the central importance of commercial practices, I am borrowing a methodology that has been used extensively by social historians of science. Literature in the history of early modern science has in fact demonstrated the key importance of practice as the site where a new collaboration between practical knowledge and academic natural philosophy became possible. Thanks to this exchange between theoretical and practical knowledge, the use of instruments, of mathematical tools, and of experiments gained a central role in European science (Zilsel 1942; Taylor 1954; Shapin and Schaffer 1985; Johnston 1991; Shapin 2010; Cormack, Walton, and Schuster 2017). The historian interested in the economic impact of knowledge can find interesting perspectives in this literature, which has extensively investigated the social circulation of knowledge and its potential to bring about social and cultural change. In this paper, I am framing the question of the economic role of socially distributed knowledge as a question in between economic history and socio-intellectual history. In doing this, I am following Mokyr's own call for a closer integration between economic and intellectual history (Mokyr 2017, xiii-xiv), to which I am adding the perspective and methodologies of the 'social turn'. If we are interested in the economic impact of knowledge, in fact, we should not only ask what kind of knowledge was developed at different moments of time, but we should also – and more importantly – ask who was acting on the basis of such knowledge, in which social and institutional context, and with what institutional and economic outcomes.

In this paper, I use this methodological framework to investigate the adoption of Hindu-Arabic numerals in commercial practices in Italy and England. As the positional numeral system provided a mathematical foundation to the innovations of the commercial revolution, studying its diffusion provides a proxy to trace the useful knowledge associated with advanced commercial practices. Relying on a number of accounting documents, manuals, diaries, and other sources, I use Hindu-Arabic numerals as a yardstick to reconstruct the development, transmission, and spillover effects of applied knowledge in Italy and England. In both cases, it is possible to identify a process of change which started off informally in commercial practices, was subsequently institutionalised, and eventually spilled over to other fields. This case study makes it possible to both investigate the role of practical knowledge in pre-modern economic development, and to observe a number of analogies between changes in practices, institutions, and the broader society that linked the commercial revolution to the little divergence. The evidence provided in this paper raises the hypothesis of a continuity in the transmission of practical knowledge from the commercial revolution to the onset of the little divergence, in what can be thought of as a coherent innovation cycle.

The paper is divided into three sections. Section 1 discusses the adoption of Hindu-Arabic numerals in late medieval and early modern Italy. Section 2 discusses the same phenomena in late medieval and early modern England in comparative perspective. Section 3 wraps up and concludes.

1. The adoption of Hindu-Arabic numerals and the culture of Italian abacus mathematics

The 'commercial revolution of the 13th century' was a watershed moment in European economic history (De Roover 1953, 80).[1] This profound change in commercial practices started in the Italian city states of the 13th and 14th centuries, whose merchants introduced a wave of key innovations that led to the emergence

[1] «By a commercial revolution I understand a complete or drastic change in the methods of doing business or in the organization of business enterprise just as an industrial revolution means a complete change in the methods of production […]. The commercial revolution marks the beginning of mercantile or commercial capitalism, while the industrial revolution marks the end of it».

of new markets and to new forms of enterprise.[2] Tuscan merchant-bankers developed the first European international commercial-banking companies, with branches located in the main hubs of European commerce (Tognetti 2015, 704; Spufford 1988, 253). The corporate structure of these firms was often based on an organisational innovation, i.e. the so-called *compagnia* (or 'partnership') contract (Goldthwaite 2009, 64-66; Padgett and McLean 2006).[3] In the early 14th century, Tuscan *compagnie* became the most important commercial enterprises in Europe, and Tuscan merchant-bankers consolidated a monopoly on European financial markets that lasted over a century (Tognetti 2015; Kaeuper 1973; Sapori 1926; 1944). The complex structure of these companies promoted a strong experimentation in accounting techniques, which led to the invention of double-entry bookkeeping (Padgett and Powell 2012; Parker and Yamey 1994; Nobes 1984; Lee 1977; De Roover 1956; Yamey and Littleton 1956). The international nature of these firms, moreover, led to the development of financial innovations, the two most important of which were the bill of exchange and insurance contracts (Ceccarelli 2012; Melis and Dini 1975). Bypassing the theological ban on interest rates, the bill of exchange made it possible to extend credit at interest, and it thereby revolutionised European financial markets (Adrian R. Bell, Brooks, and Moore 2017; Rubin 2010; Kohn 1999; Mueller 1997, 293-307; Spufford 1988; De Roover 1944; 1967).

Influences from the east had a key role in these developments (Abulafia 1997). The literature on the commercial revolution often overlooks the fact that the merchant-bankers of the commercial revolution were the first European economic agents to adopt Arabic arithmetic in their commercial practices. Before the adoption of the positional numeral system, Europeans used a number of reckoning technologies, such as tallies and the counter abacus (or casting counter) (Day 2013; Baxter 1989; Barnard 1916). Thanks to the principle of positionality and to the symbol for zero, Hindu-Arabic numerals make it possible to handle the fundamental mathematical operations relying on only ten figures (Ifrah 2000, 679). Moreover, the positional numeral system was adopted together with the symbolism for fractions. This was an important breakthrough, as Roman numerals allow to handle only a limited set of rational numbers. Roman 'fractions' were in fact limited to duodecimal fractions, based on the ancient subdivision of Roman units (Yeldham 1927; Maher and Makowski 2001). A system in which each fraction is represented with a different symbol is structurally limited in its handling of rational numbers. On the contrary, the positional numeral system provided a systematic way to write

[2] The concept of the 'commercial revolution' has also been used to identify a series of wider socio-economic phenomena occurring in this period (Lopez 1976). Following De Roover's original definition, however, the concept of the 'commercial revolution' used in this paper is limited to business methods.

[3] This new corporate structure made it possible to both make mid-term business strategies and to provide the necessary flexibility to exploit unforeseen business opportunities. In Florence, where it was non-notarised, the *compagnia* contract also made it possible to considerably reduce transaction costs. It is interesting to note that the mediation of notaries remained in use for a long time for transactions involving actors who were not part of the tightly-knit network of international merchants (Tognetti 2018).

fractions using only ten symbols, and made it potentially possible to handle *any* rational number.

These characteristics are key to understand the adoption of Hindu-Arabic numerals among merchants of the commercial revolution. A first source attesting the exchanges between the Arabic civilisation and the Italian maritime republics is the *Liber abaci* by Leonardo Fibonacci (c. 1228). This is an extensive *summa* of the mathematical knowledge of the time, combining the Arabic, Greek, and Latin traditions (Giusti and D'Alessandro 2020; Folkerts 2004). While previous Latin translations of Arabic mathematical works were not concerned with the practical applications of mathematics, Fibonacci's work showed explicitly how Arabic arithmetic could be applied to solving commercial and financial problems (Franci 2002; Giusti and Petti 2002; Goetzmann 2003; Biggs 2009).

Solving mathematical calculations related to exchange was of key importance in the development of the innovations of the commercial revolution. For example, the Italian monetary system of the time generated a need to handle these calculations. As the monetary system was trimetallic and the relative value of coins was continuously subject to change, Italian late medieval accounts are kept in the so-called moneys of account, or 'ghost money' (Lane and Mueller 1985, 3-13; Cipolla 1956, 38). This means that every transaction occurring in cash required that the accountant calculate the exchange rate between the actual currency and the unit of account used in the ledger. As the relative price of these moneys could have taken any value, calculating ratios between these units implied calculating with almost any possible rational number. Similar calculations concerned both merchant-bankers active in international trade and local merchants since moneys of account were used also by small shopkeepers (Goldthwaite 2009, 355). Moreover, problems of exchange were essential in the development of the bill of exchange, which was based on the calculation of exchange rates. One can wonder to what extent it would have been possible to develop these innovations relying on a numeral system – the Roman one – that was structurally limited in handling rational numbers.

Innovations such as double-entry bookkeeping, the use of a symbolic numerical notation, and the bill of exchange were shared among a community of users, as each party needs to recognise and trust the meaning and validity of their conventions, in a sort of network effect. In other words, a large subset of the mercantile community had to adopt the innovations of the commercial revolution for them to achieve their full potential. As a consequence, following the first experimental period in which practical arithmetic was transmitted informally, Italian city states developed an institutional setting that aimed at making a wide social diffusion of these practices possible, thanks to the creation of a specialised schooling system. While in the early middle ages basic education had been provided by church schools, between the late 13th and the 14th century Italian city states revolutionised the educational sector by founding schools that employed lay teachers, provided teaching in the vernacular, offered intensive curricula, and were often publicly funded (Black 2007, 186-87). As it was not possible to master the new commercial practices without being literate and numerate, these schools taught basic grammar and practical arithmetic to prospective merchants, artisans, and to members of urban society more generally. By providing a training in the fundamentals of the techniques of the commercial revolution, this schooling system made possible a wide adoption of the innovations of the commercial revolution in urban societies.

In most cities, pupils were taught practical arithmetic in specialised schools, the so-called 'scuole d'abaco' (Grendler 1989, 44-77; Arrighi 1966; Goldthwaite 1972).[4] Despite what their name might suggest, abacus schools taught both how to use traditional reckoning techniques (such as the counter abacus) and arithmetic with Hindu-Arabic numerals.[5] By the 15th century, abacus schools were founded in most central-northern Italian cities, and there is evidence of their presence in some centres of the south (Ulivi 2008). As they were often publicly funded, these schools were established as a deliberate policy to promote local useful knowledge. In some cases, this intention is explicitly attested in local archives. For example, in the 14th century the abacus school of Pistoia was founded on the premises that without practical arithmetic local merchants and artisans could not have exercised their activities appropriately («Sine scientia abaci mercatores et artifices utiliter et bene se exercere non possunt») (Grendler 1989, 22). In major cities, such as Florence and Venice, the demand for this kind of training was sufficiently strong that practical arithmetic schools did not need public support, as the fees paid by their students covered their financing (Black 2007, 545-611; Ulivi 2002b). At the same time, these fees were not particularly high, as abacus-school pupils came from a wide social spectrum, which comprised both families of the mercantile élite and those of small shopkeepers (Van Egmond 1977; Goldthwaite 1972).

The teachers who worked in these schools show interesting characteristics as well. While in the 12th century most teachers were clergymen affiliated to church schools, by the end of the 13th century masters active in Italian city states were mostly laymen whose work was embedded in the society of the commune (Black 2007, 191). Apart from working as teachers of practical arithmetic, abacus masters were often employed by the commune as expert reckoners and as surveyors (Goldthwaite 1972, 428; Ulivi 2002a; Grendler 1989, 22-23). Abacus masters had a distinct professional identity. For example, they created a separate membership in mercantile guilds, as by 1316 it is possible to find an *ars magistrorum abaci* in Milan and in Venice (Van Egmond 1977, 13). Moreover, abacus masters were keenly competitive. They competed to secure higher numbers of pupils, and challenged each other to solve mathematical problems of increasing difficulty, both within and across cities (Goldthwaite 1972; Ulivi 2015). In terms of social status, abacus masters generally belonged to a urban middle class, as their tax reports place them in a comparable position to that of shopkeepers, artisans and small merchants (Martines 1963; Van Egmond 1977, 8-14; Tognetti 1995).

The main sources available to study abacus mathematics are the so-called abacus manuals. These texts are written in Italian vernaculars, and their entire tradition

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[4] It seems that in the Venetian state pupils were taught grammar and practical arithmetic in parallel, in what Grendler called «vernacular combination schools» (Grendler 1989, 22-23). Despite these regional variations, the mathematical training provided by these schools was substantially the same.

[5] The name «abacus school» is derived from the vernacular 'scuola d'abaco», a name that can be misleading. In late medieval Italian, «abaco» was used to indicate not just the reckoning board, but any reckoning device.

can be considered as a vernacularisation of the mathematics that was transmitted from the Arabic world to southern Europe across the Mediterranean, as exemplified by Fibonacci's 13th-century *Liber abaci*. The importance of the tradition of abacus mathematics is shown by the number of extant texts, as we know over 280 manuscripts and over 150 printed editions of abacus manuals written between the late 13th century and 1600 (Van Egmond 1980). As most authors of these texts were abacus masters, it is possible to hypothesise that these texts mainly circulated in the context of abacus schools. In some cases, we also know that they were passed down across generations of masters (Arrighi 1966; Ulivi 2004, 70-71; Murano 2015; Danna 2019). Abacus manuals mainly consist of long lists of worked examples (called *ragioni*), and their theoretical sections are kept to a bare minimum. These *ragioni* are often ordered according to their domain of application (for example: problems of exchange, of conversion, of division of profits and losses, etc.). This structure suggests that these texts were used as repositories of the mathematical problems explained by abacus masters while teaching. This is particularly true for early manuals, as there is evidence that with time these texts increasingly circulated in the hands of other practitioners.

The oldest abacus manuals were written at the end of the 13th century. Starting from that period, the increasing number of extant documents suggests that there was an acceleration in the production of these texts in the 14th century. Let us consider a paradigmatic example of one of these manuals: Paolo dell'Abaco's *Trattato di tutta l'arte dell'abaco*. The author (c. 1300-c.1366) was a prominent abacus master in 14th-century Florence who worked in the abacus school of Santa Trinita and wrote different works. Judging from the number of extant copies, Paolo dell'Abaco's *Trattato di tutta l'arte dell'abaco* was the most successful abacus manual of the century, with ten manuscripts attesting the work (Van Egmond 1980; Murano 2015; Danna 2019, 259). The manuscript Fond. Princ. II. IX. 57 of the National Library of Florence is probably the oldest copy, and may have been written by Paolo himself (Van Egmond 1977, 12). It is a manuscript of 188 paper folios which has been drafted by a single main hand, but also shows a number of subsequent hands that extended the initial text.

The manuscript opens with miscellaneous folios that include a medical section. The main text of the *Trattato* starts at folio 17r, with a short incipit: «Al cominciamento del nostro trattato sarae scritta e provata tutta l'arte dell'abacho gieneralmente ciò che ddire se ne puote».[6] The same folio reports a table of contents, which is followed by equivalence tables, by an introduction of the positional numeral system (fol. 23r), and of the fundamental arithmetical operations, first with integers and then with fractions (fols. 25-42). Following this theoretical preface, the manuscript presents a long section on the practical applications of mathematics which include conversions, calendrical calculations, payments, monetary exchange, alloying, division of profits and losses, barter, interest rates (both simple and compound), recre-

[6] «At the beginning of our treatise will be written and proved all the art of the abacus in all its aspects, i.e., everything it is possible to say about it».

ational problems,[7] and a section on practical geometry that shows several applications for land and architectural surveying (fols. 43-142). Folios 142-156 include a further section on medicine where astronomical calculations are used to identify the most appropriate time to give medical remedies. Folios 157-181 contain a miscellany of mercantile problems, some of which are solved with algebraic methods. The last folios (182-188) provide a further section on astronomy/astrology. While it is possible to find a broadly coherent structure in this manuscript, it is an open document characterised by numerous stratifications, rather than a systematic text. It is possible that this manuscript was among the books that Paolo dell'Abaco mentioned in his testament, and which were eventually given to a younger abacus master, Antonio Mazzinghi da Peretola. If this was the case, this manuscript would be particularly significant, as the several hands found therein would correspond to different generations of masters who used and integrated the text. Moreover, this manuscript would also provide direct documentation of the kind of mathematics that circulated in abacus schools (Danna 2019).

The mathematics found in these texts is an inherently applied knowledge. As can be seen from the contents listed above, the first and most important field of application was the economy. The text presents sections explicitly dealing with how to handle interest rates – a topic which at the time was highly debated in other social and cultural contexts – and uses the most advanced mathematics of the time – algebra – to solve mercantile problems. Moreover, this manuscript also shows that around the middle of the 14th century abacus mathematics was starting to be applied in fields beyond commerce. Paolo himself was active as a mathematical practitioner, as he worked as a consultant for the commune, advised on military matters, probably worked as a physician, and did experiments in astronomy using instruments. His work in astronomy and measurement was influential, as it seems that Paolo dal Pozzo Toscanelli resorted to some of Paolo's calculations when working on the problem of calculating longitude at sea (Murano 2015; Danna 2019, 255-66). Paolo dell'Abaco's testament also illustrates his interests in these disciplines, as it mentions books and a number of instruments pertaining to astrology and medicine whose detailed description has recently been identified in a Florentine inventory (Ulivi 1996; Murano 2015).

In other words, Paolo dell'Abaco's *Trattato di tutta l'arte dell'abaco* shows that around the middle of the 14th century abacus mathematics was an essential knowledge for anyone engaging in market exchanges. Moreover, it also shows that this kind of knowledge was starting to spill over into other fields, such as surveying, medicine, and astronomy. With time, these spillovers increased, with practical arithmetic and Hindu-Arabic numerals reaching further afield. This can first be ob-

[7] The so-called 'recreational problems' are miscellaneous exercises in which the reader is required to identify the correct resolution method among the several formulae used in these texts. On the one hand, these problems can be thought of as a form of amusement (similar to contemporary mathematical puzzles). On the other hand, these sections also played an educational role. While most sections of abacus manuals are subject-specific – and therefore consistently apply the same resolution methods – recreational problems trained the reader to identify the correct resolution method: an essential skill once the learner left the abacus school and faced the breadth of problems stemming from commercial practices.

served from evidence about who owned practical arithmetic manuals. While early manuscripts - such as Paolo's *Trattato* - were mostly circulating in the hands of abacus masters, with time there is evidence of an increasing diversity of owners of abacus texts. By the second half of the fifteen century, it is possible to find manuscript manuals that belonged to a Florentine carpenter,[8] a medical practitioner from Cremona,[9] a Bolognese rug trader,[10] and several artists active across Italian cities.

Artists provide a particularly interesting case, as Hindu-Arabic numerals were used in the development of a key innovation of Italian renaissance painting, i.e., linear perspective. This can not only be observed from their preparatory sketches - where Hindu-Arabic numerals and fractions appear regularly[11] - but also from the fact that some protagonists of Italian linear perspective wrote texts of abacus mathematics. For example, Piero della Francesca was not only one of the most prominent artists of his time, but also a writer of geometry and mathematics, as one of his first written works is a full-fledged abacus manual (Arrighi 1970; Dalai Emiliani et al. 2012). Architects were influenced by abacus mathematics as well. In Vasari's *Le vite de' più eccellenti pittori, scultori e architettori*, Filippo Brunelleschi is the first artist who is said to have attended an abacus school during his youth (Bellosi and Rossi 1986, 294). In his *Libri della Famiglia*, Leon Battista Alberti recommended that youngsters attend abacus schools (Romano, Tenenti, and Furlan 1994, 73-74). Hindu-Arabic numerals were also employed in naval architecture, as shown by the sketches for the construction of galleys copied – probably from original documentation of the Venetian arsenal – by Michael of Rhodes in his 15th-century manuscript (Long et al. 2009). By the 16th century, abacus mathematics had become so widespread in Italian urban societies that Girolamo Cardano (1501-1576) could claim in the incipit of his *Artis arithmeticae tractatus de integris* that practical arithmetic was essential for the economic success of any professional:

> Itaque factum est ut Oratores, Poetae, Iurisconsulti, Medici, Agricolae, Architecti, Exercituum duces ac demum omnes quotquot sunt operibus suis aut aliqua ratione illustres nihil ab hac [numerandi scientia] efficere possint, cum plures etiam hac sola industria locupletes evadant atque inter hos mensarii, collibytae, mercatores, quibus nemo vel promptius vel facilius ditatur. Laborant Medici Rhetoresque tota vita, ut quater sestertium (nec id frequentius) lucrifaciant, at hi quam paucis annis centies sestertium congregant (Cardano 1663, 10; 117).[12]

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[8] Florence, Biblioteca Marucelliana, ms. A. c. s. 47.

[9] Florence, Biblioteca Mediceo-Laurenziana, ms. Ash 1128.

[10] Bologna, Biblioteca Universitaria, ms. 1612.

[11] This is evident, for example, in Leonardo da Vinci's *Codice Atlantico* or Piero della Francesca's *De prospectiva pingendi* (Marinoni 1973; Dalai Emiliani et al. 2017).

[12] «We have come to the point that orators, poets, jurisprudents, physicians, farmers, architects, army leaders and actually all those who are somehow reputed for their works or for some other reason cannot accomplish anything without that [the science of numbers or arithmetic]. In fact, many become wealthy only thanks to that activity [of counting numbers], among them bankers, money exchangers and traders. None grows rich more rapidly

While Cardano's incipit represents a rhetorical exaggeration, it shows that, by the 16th century, abacus mathematics had become an integral part of Italian urban culture. It was a knowledge that was widely shared across social strata and across cities, and it was applied to a variety of fields, such as mercantile practices, shipbuilding, architecture, and painting. In his reconstruction of the social history of pictorial style, Baxandall discussed at length the distinctively quantitative characteristics of 15th-century Italian artistic taste. He argued that this sensibility was so widespread in 15th-century societies that it is possible to identify a quantitative 'period eye' shared across the public. The reconstruction of this quantitative culture is based on Baxandall's discussion of abacus mathematics and abacus schools (Baxandall 1972). More recently, Goldthwaite has made similar claims concerning the practice of accounting for renaissance Florence (Goldthwaite 2015). If it is possible to claim that practices that made use of abacus mathematics (such as linear perspective and accounting) can be considered as forms of culture in renaissance Italy, then it should be possible to consider the arithmetic on which these practices were founded as part of this urban culture as well.

2. The spread of practical arithmetic in England and the culture of the 'mathematicalls'

Following its origins in the 13th-century Mediterranean, practical arithmetic spread to the rest of the European continent. The evidence extant on the publication of practical arithmetic manuals shows that the spread of this mathematics followed a south-to-north axis, with northern European countries adopting this mathematical knowledge well into the 16th century (Danna 2021; 2022). This evidence suggests that there may also have been a continuity in the diffusion of advanced business methods between the commercial revolution and the little divergence. The case of England is particularly interesting, as it sheds light on the varying social circulation of this mathematical knowledge. England was in fact an early adopter of Hindu-Arabic numerals in scholarly contexts, but it was a late adopter of the same mathematics in practical contexts. Interestingly, once Hindu-Arabic numerals started to circulate in English vernacular contexts, it is possible to observe a series of changes that are akin to the ones outlined above for the Italian case.

The first Latin translations of Arabic arithmetic works were carried out in 12th-century al-Andalus by scholars such as Robert of Chester and Gerard of Cremona (Ambrosetti 2008; Djebbar 2003; Folkerts 2001; 2003; Folkerts and Kunitzsch 1997). These translations were at the origin of the tradition of the Latin *algorismi*, i.e. brief mathematical primers introducing Hindu-Arabic numerals and the methods to

and more easily than they! Physicians and orators work their whole life to spare a quarter sesterce (and they do not often succeed), whereas those people can amass hundreds of sesterces in very few years». English translation from (Omodeo 2017, 324). The *Artis arithmeticae tractatus de integris* was published as part of Cardano's *Opera omnia* in 1663, but its remarks concern the 16th century, as Cardano died in 1576.

use them to calculate the four fundamental operations. These texts spread in European monasteries and universities, as Hindu-Arabic numerals were used in fields where advanced calculations were needed, such as astronomy (Nothaft 2014). English scholars were quick to adopt these techniques, as a few 12th-century *algorismi* from England are extant. The catalogue of Medieval Libraries of Great Britain – which aims to record evidence on all extant medieval books that belonged to a British library in the middle ages – includes a number of references to *algorismi*.[13] Among these is one of the oldest copies of the so-called *Dixit Algorizmi*, which was probably written in the monastery of Bury St. Edmunds (Karpinski 1921; Vogel 1963; Crossley and Henry 1990).[14]

However, the circulation of these techniques remained limited to the learned classes. An interesting example of this is provided by the so-called *Dialogus de scaccario*. This is essentially a government memo, in which royal treasurer Richard FitzNeal explains how the English Exchequer was run. Fiscal revenues were recorded using a large exchequer to cast calculations with counters. When explaining how this reckoning tool was used, the author makes a revealing reference to Arabic arithmetic, excluding its use in this context:

> Quid ad calculatorem
> Huius autem hec est ratio secundum consuetum cursum scaccarii non legibus arismeticis. Memoriter, ut credo, dixisse me retines scaccario superponi pannum uirgis distinctum in cuius intersticiis numerales acerui collocantur. Porro calculator in medio lateris residet ut pateat omnibus et ut liberum habeat ministra mannus excursum (Amt 2007, 36-37).[15]

As a learned churchman, Richard FitzNeal was probably aware of the Arabic methods of calculation. However, to carry out calculations that involved laymen – like sheriffs, who were for the most part illiterate – he preferred to use a counter abacus (C. Johnson 1950, xxiv-xxxvi).

This hesitation to adopt Hindu-Arabic numerals in English practical contexts persisted for a long time, and it was not facilitated by the tense relationships between Italian and English merchants. For centuries, Italian merchants were the only practitioners active in England who mastered the techniques of the commercial revolution. By 1277, these merchants were active in English trade and finance, holding a dominant position in the export of wool, advancing loans to the crown, and administering the church's tenth in the kingdom. This is the period in which Edward I granted to the community of Italian merchants the area in east London

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[13] This resource is accessible online at http://mlgb3.bodleian.ox.ac.uk

[14] Cambridge University Library, ms. Ii.6.5. On the library of the abbey of Bury St. Edmunds in this period, see (Gransden 2007; 2015).

[15] «But the system of this is according to the usual course of the Exchequer, not by the rules of Arabian arithmetic. You remember my saying, I imagine, that a cloth is laid on the Exchequer table ruled with lines, and that the coins used as counters are placed in the spaces between them. The Accountant sits in the middle of his side of the table, so that everybody can see him, and so that his hand can move freely at its work» (C. Johnson 1950, 24-25).

that is still known as Lombard Street. While royal and church officials relied on the financial services of the Italians, they did not know how their techniques worked. For example, in 1291 a dispute involving bills of exchange was heard by Exchequer officials. As – by their own admission – these officials were not competent in these practices, they preferred to appoint arbitrators from the community of Italian merchants to settle the case (Rawcliffe 1991, 100-101). This penetration of Italian finance in England reached its peak in the late 1330s, when the financial difficulties of the English crown determined the bankruptcy of some major Tuscan merchant-banking companies (Sapori 1934; 1955; Bell, Brooks, and Moore 2009; Bell, Brooks, and Moore 2009; Tognetti 2014).

Relations between Italian merchants, the English crown, and the community of English merchants remained difficult for a long time. Following the bankruptcies of the 1330s, the second half of the century was possibly a period in which the presence of the Italian community was reshaped, but by the 15th century Italian galleys were a key link for English international trade (Holmes 1960; Bradley 1992). Moreover, Italians constantly held a dominant role – if not a monopoly – on international exchange throughout the period. This created tensions which surfaced explicitly in the 15th-century *Libelle of Englyshe Polycye* (1436). The author of this pamphlet, probably an English merchant active in international trade, argued that Italian merchants bought in England on credit, sold for cash, and invested this money in bills of exchange purchased by English merchants (Tanzini and Tognetti 2012, 132). In his own words, they would «wipe our nose with our owne selve» (Holmes 1961, 201). The perception of a general economic downturn around the middle of the 15th century led to the introduction of stricter rules for 'alien' merchants, whose hosts were required to provide official reports of their activities (H. Bradley 2012). In 1456, a riot that broke out in London was triggered by a series of attacks against the Italian mercantile community (Bolton 1986). Similar tensions were still at play in the following century, for example with the Merchant Adventurers calling on the monarchy to adopt policies specifically aimed at penalising Italian merchants, as documented in the *Declaration of the misdemeanours of Italians* of 1561 (Ramsay 1973, 31).

While these tensions did not favour knowledge exchange between the two communities, there were also opportunities for – or necessity of – local cooperation, especially far from the rivalries of the court. An interesting example is provided by Southampton, which in the 15th century emerged as the main hub for Italian shipping in England, and had a comparatively large community of Italians merchants and sailors. Everyday life between the Italian and local English communities was characterised by a continuous negotiation between factional tensions and the benefits of collaboration (Ruddock 1951; 1946). Upon his arrival in Southampton in 1429-30, Luca di Maso degli Albizzi, captain of the Florentine galleys, reported in his diary that he was welcomed by William Soper, collector of the customs of the port and keeper of the king's ships. Soper hosted Luca di Maso in his country estate and showed him the main ships of the royal navy. A quick observation about the accounting methods used by Southampton customs officials opens the possibility that Luca di Maso exchanged some knowledge concerning bookkeeping with them (Mallett 1967, 259). It may be as a consequence of this kind of local knowledge exchanges that Southampton collectors were among the first English officials to use bills of exchange drawn on Italian companies in London to transfer tax revenues to the Exchequer (Rose 1982, 16-17). Moreover, the account books of Southampton show the use of Hindu-Arabic numerals by the 15th century, while English public accounts tend to employ Hindu-Arabic numerals at a much later date, starting from as late as the 17th century (Jenkinson 1926). For example, Hindu-Arabic numerals appear in the port accounts by Robert Florys of 1435-36, and in the Southampton steward's accounts dated 1457-58 and 1492-93 (Foster 1963; Thick 1995; 1999). Interestingly, the account book written under the direction of William Soper himself reports Hindu-Arabic numerals, providing what may be among the earliest appearances of the new notation in English public accounts.[16]

These documents suggest a pattern of adoption of Hindu-Arabic numerals in English vernacular contexts similar to what we have seen for Italy. They suggest both that this adoption was driven by the mercantile classes, and that the early adopters of the new notation were also among the early adopters of the techniques of the commercial revolution. This is confirmed by subsequent accounts kept by English merchants. For example, the letters of the Celys (1472-1488), a family active in the international wool trade, show that these merchants were acquainted with the new notation. Moreover, it seems that they were also among the first English merchants to use bills of exchange (Hanham 1975; 1985, 165). In the first half of the 16th century, the accounts of the Kytson family – active in trade with the Low Countries – show that these merchants used Hindu-Arabic numerals not just to report quantities, but also to calculate.[17] One of the first English account books to show an influence of double-entry bookkeeping – the ledger by Thomas Howell (1517-28), also active in international trade – reports Hindu-Arabic numerals as well (Connell-Smith 1951; Winjum 1971).[18] Around 1530, Richard Hill, a grocer from London active in the wool trade with the Low Countires, wrote a miscellaneous memorandum-book that includes a section on practical arithmetic and conversion tables for wool prices across the Channel.[19] Interestingly, very similar patterns of adoption of Hindu-Arabic numerals in accounting sources can be found in the Low Countries. Also in this context, it is possible to observe a piecemeal adoption of Hindu-Arabic numerals in accounting sources, with private accounts playing the leading role, and public accounts following at a distance of at least a number of decades.[20]

This chronology of the adoption of practical arithmetic suggests that the first circulation of Hindu-Arabic numerals in England was driven by merchants active in international trade, who were exposed to the influence of foreign commercial techniques and faced operations of exchange in their business practices. The first circu-

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[16] Greenwich, National Maritime Museum (ms. PLA/18), f. 41v.

[17] Cambridge University Library, Hengrave Hall Mss Collection, Hengrave 78/1-4. The accounts belonging to Thomas Kytson (1529-1540) have recently been published in (Brett 2020).

[18] The ledger of Thomas Howell is kept at the Drapers Company in London.

[19] Oxford, Balliol College, ms. 354, fols. 186r-189v.

[20] I am grateful to Erik Aerts for sharing with me the early drafts of his study on the use of Hindu-Arabic numerals in accounting sources of the Low Countries, which is forthcoming in the *Journal of European Economic History*.

lation of this knowledge was most likely informal, but it generated an incipient demand for more structured training in practical arithmetic. As far as the available evidence makes it possible to reconstruct, this incipient demand that emerged among international English merchants is similar to the initial circulation of practical arithmetic among Tuscan merchant-bankers during the 13th century. As in the Italian case, this informal circulation of practical arithmetic progressively grew until it required some form of formal training in practical arithmetic. Once this demand was sufficiently strong, it was met by the foundation of the first vernacular schools of practical arithmetic in England.

England was the latecomer in this innovation cycle that started from the Mediterranean. Interestingly, practical arithmetic spread progressively from the south to the north of Europe not following the main routes of international trade, but through an inland network based on proximity. The key channels for this transmission were master-pupil relationships and the migration of skilled people (Danna 2021; 2022). The foundation of practical arithmetic schools also followed this path. Starting from the middle of the 15th century, we have the first evidence of practical arithmetic schools in the south of France and Upper Germany. Among the protagonists of this early phase were Nicolas Chuquet, who was active in Lyon in the 1480s, and Ulrich Wagner, who ran a school of practical arithmetic in Nuremberg in the second half of the 15th century (Benoit 1988; Flegg 1988; Gärtner 2000, 189). From these first cities north of the Alps, practical arithmetic schools spread to other centres. The first evidence of practical arithmetic schools in the Low Countries is from the early 16th century, with Antwerp as the hub for this kind of training (Kool 1988; Meskens 2013). From the north of the continent, practical arithmetic schools eventually crossed the Channel towards England.

The first masters of practical arithmetic active in London were in fact immigrants from the continent. In the preface to his *The welspring of sciences* (1574), Humfrey Baker complained that continental masters active in London in the 1570s still argued that their knowledge of practical arithmetic was superior to that of English masters:

> For when I perceaued the importunitye of certayne straungers not borne within this lande, at this present, and of later daies so farre proceadinge, that they aduanced and extoiled them selues in open talke and writinges, that they had attained such knowledge and perfection in Arithmeticke, as no English man the like: Truly me thought that the same report not onely tended to the dispraise our Countreymen in generall: But touched especially some others & me, that had travailed & written publiquely in the same facultye. For unto this same effecte they have of late painted the corners and postes in every place within this Citie with their peevishe billes, makinge promise, and bearinge men in hande that they coulde teache the summe of that Science in breife Methode and compendious rules suche as before their arrivall have not bene taught within this realme.[21]

[21] Humfrey Baker (1574), *The welspring of sciences*, fols. 6r-v.

This evidence suggests, therefore, that the practical arithmetic schools of England were distant descendants of the model of Italian vernacular schools, and close descendants of the first practical arithmetic schools founded in the north of the European continent.

This hypothesis is confirmed by the first manuals of practical arithmetic published in England, as these texts show strong influences from the continent. The first evidence of such a manual written in English is preserved in a single leaf kept in the British Library.[22] This is the frontpage of a manual titled *Art and science of arithmetic*, printed in 1526 by Richard Fakes, and the colophon introduces the work as an English translation of a manual written in French. Moreover, the printer himself was an immigrant from the continent, as he was a Norman by birth and his original name was «Faques» (Williams 2012, 166). The second English practical arithmetic is the anonymous *An introduction for to lerne to recken*, printed in 1536/37 and in 1539. This manual is not presented as a translation of a work written on the continent, but its language shows strong influences from French and Netherlandish. Also in this case, the biography of the printer is significant, as John Herford was a Fleming who started to operate as a printer in England in the 1530s. This evidence confirms the influence of sources from the north of the European continent for the origins of the English tradition of practical arithmetic (Bockstaele 1960; Richeson 1947; Williams 2012).

These early anonymous works were followed by manuals written by the first generation of English practical arithmeticians. The most influential among these was Robert Recorde (c. 1512-1558). Born into a family of Welsh middle-class merchants, Recorde studied medicine in Oxford and Cambridge, and worked as a physician and as a tutor of practical arithmetic. He was the author of a series of practical texts and was also active as an early mathematical practitioner, serving as an official in royal mints. Recorde died prematurely in 1558 in a debtors' prison, but the influence of his works lasted long after his death (Roberts 2016; Roberts and Smith 2012; Williams 2011). In 1543, Recorde published his *The Ground of Artes Teachyng the Worke and Practise of Arithmetike*. As suggested by its title, this was a foundational work which covered the essentials of practical arithmetic with Hindu-Arabic numerals. The text introduced the new numeral system, showed how to make calculations with integer numbers, and included a final section on calculations with the counter abacus and finger reckoning. In his preface to the reader, Recorde lamented the low consideration given to arithmetic in English society, and addressed his work to vernacular readers, who could use the manual to self-teach in case they could not afford a formal education:

> Yet am I bolde to put my selfe in presse with such abylyte as God hath lent me, though not with so greate conynge as many men, yet with as greate affection as any man to helpe my countre men, I wyll not cease dayly (as much as my small abylyte wyl suffre me) to endyre some suche thynge that shalbe

[22] London , British Library, Bagford (formerly Harleian 5919), item 178.

> to the enstruction, though not of learned men, yet at the leaste of the vulgare sorte […] but some wyll lyke this my boke above any other Englysche Arithmetike hetherto wryten, and namely suche as shall lacke estructers, for whole sake I have so playnely set forthe the examples, as no boke (that I have sene) hath done hertherto, which thyng shall be great ease to ye rude reader.[23]

The Ground of Artes had remarkable success, as it was reprinted over 40 times until 1699. Starting from the 1552 edition, Recorde included in the text calculations with fractions, the 'golden rule' of three, and a new set of practical problems. New editions appeared after Recorde's death, further updated by two prominent mathematical practitioners – John Dee (1561) and John Mellis (1582) – who also added a section on bookkeeping. Along these updates, the parts on calculations on the abacus and finger reckoning were dropped.

While *The Ground of Artes* was Recorde's most popular text, he also wrote other works. *The Urinal of Physike*, a work on medicine, was published in London in 1547. In 1551, he published *The Pathway to Knowledge*, the first English exposition of practical geometry. In 1556, he published *The Castle of Knowledge*, the first introduction to astronomy written in English, which also mentions Copernicus' new heliocentric theory. *The Whetstone of Witte* appeared in 1557, and, building on continental sources, provided the first English exposition of algebra. In order to make equations easier to handle algorithmically, in this work Recorde put forward the idea of using two parallel lines as a sign for equality ('='). This is the first known appearance of the equals sign, making *The Whetstone of Witte* a key text in the history of mathematical notation (Cajori 1928). As stated explicitly in the prefaces to his texts, Recorde sought to provide a foundation for a new English practical science. His works covered practical arithmetic (1543), medicine (1547), practical geometry (1551), astronomy (1556), and algebra (1557), often for the first time in the English language.

There is evidence that Recorde's works circulated among English practitioners. John Mellis, who was one the first writers of bookkeeping in English, wrote in the preface to his 1596 edition of *The Ground of Arts* that he had been introduced to practical arithmetic through Recorde's manual. He subsequently attended a vernacular school, became a practical arithmetic master himself, and eventually agreed to publish a new edition of Recorde's text following a growing demand for this kind of books. The text circulated among mariners. It is quoted in almanacs covering celestial navigation in the 1570s and in manuals of navigation with the compass in the 1580s (Williams 2011, 218-19). *The Castle of Knowledge* was included in the small library of the first ships that sailed in search of the Northwest passage. John Dee, who edited an edition of *The Ground of Artes*, himself spent time on board these ships, instructing mariners in practical arithmetic, geometry, and astronomy (Patterson 1951, 209-10). The majority of surviving copies of English practical arithmetic manuals presents marginalia, showing that these texts were actually used to learn

[23] Recorde (1543), *The ground of artes teachyng the worke and practise of arithmetike*, fol. iv v, fol. vii r.

arithmetic, often passing down across generations of the same family and sometimes also reaching women (Otis 2017).

Starting from the 1550s, a growing number of schools of practical arithmetic were founded. As we have seen, in the preface to his *The Welspring of Sciences* dedicated to the Merchant Adventurers (1574), Humfrey Baker complained about the unfair competition that English masters suffered from continental masters active in London. A surviving broadside advertisement from 1590 attests that Baker had a reckoning school in London, where pupils were instructed in practical arithmetic, bookkeeping, and international exchange. Starting from the late 16th century, arithmetic increasingly appears in schoolmasters' licences, and the number of schools teaching practical mathematics grew throughout England in the following century (Otis 2017, 472-76).

This increasing demand for training in practical arithmetic was met by the growing publication of practical arithmetic manuals. Apart from Humfrey Baker's *The Welspring of Sciences* – printed at least 20 times since 1562 – it is worth mentioning Dionis Gray's *The Store-House of Brevitie in Woorkes of Arithemetike* (1577) – which included rules and definitions in rhyming verses –, Thomas Masterson's *First Booke of Arithmeticke* (1592), and Thomas Hylles' *The Arte of Vulgar Arithmeticke* (1600). The influence of the continental tradition of practical arithmetic continued during this period, as signalled by a number of translations of foreign works. Among these are François Flory's *The Practice of Cifering* (1593) – an English translation of a French work published in Antwerp in 1577 –, Claes Pietersz van Deventer's *The Pathway to Knowledge* (1596) – a translation of the author's *Practicque, om te leeren rekenen, cypheren ende boeckhouwen* –, and Christian Wurstisen's *The Elements of Arithmeticke most Methodically Delivered* (1596) – translation of the author's *Elementa Arithmeticae* (1579).

Moreover, in this period practical arithmetic started to spill over to new fields, such as navigation – as we have seen – and to military matters. In 1579, Leonard Digges published his *An Arithmeticall Militare Treatise*, the first practical arithmetic by an English author to include a section on the military applications of arithmetic. Thomas Bedwell, another mathematical practitioner, was active in surveying and military engineering (Johnston 1991, 321-30). Following the attack of the Spanish armada in 1588, the interest in these applications spiked. Cyprian Lucar translated into English Tartaglia's treatise on gunnery, which was printed with the title *Three Books of Colloquies Concerning the Art of Shooting in Great and Small Pieces of Artillery* just a few months after the attack (1588). Moreover, a group of merchants and city officials sponsored the first series of public lectures on arithmetic held in London. The lecturer, Thomas Hood, addressed his classes first of all to navy officials, covering military and maritime applications of arithmetic (Johnson 1942). The lecture series was discontinued in 1594, but in 1598 Gresham College was founded, whose faculty promoted an alliance between scholars and practitioners (Johnson 1942, 95).

This growing number of publications concerning arithmetic and its applications, together with the diffusion of mathematical practitioners in a number of levels of English society, determined the rise of a 'culture of the mathematicalls', characterised by a shared 'perception of mathematics as a vernacular, practical, accessible, and worldly activity', that was often coupled by an extensive use of instruments (Johnston 1991, 341). These mathematical practitioners held a middling position between the world of the arts and crafts and that of the universities, and had an important role in making English natural philosophy turn towards mathematisation, instruments, and experimentation (Taylor 1954; Johnston 1991, 341). A striking example of this mathematics moving upwards in the social ladder can be found in Samuel Pepys' *Diary*. Educated according to the traditional curriculum of the liberal arts, Pepys was not trained in arithmetic during his studies. Therefore, when he was appointed clerk of the acts to the navy board in 1662, he started to study practical arithmetic taking lessons from a mariner of the HMS Royal Charles:

> 4th Up by five o'clock, and after my journall put in order, to my office about my business, which I am resolved to follow, for every day I see what ground I get by it. By and by comes Mr. Cooper, mate of the Royall Charles, of whom I intend to learn mathematiques, and do begin with him to-day, he being a very able man, and no great matter, I suppose, will content him. After an hour's being with him at arithmetique (my first attempt being to learn the multiplication-table); then we parted till to-morrow (Latham and Matthews 1996).

John Wallis, one of the founders of English algebra, recorded in his autobiography that he first came to know about arithmetic in 1631 not during his studies in Cambridge, but from the textbooks of one of his brothers, who attended a vocational school that covered the standard curriculum of practical arithmetic: «the Practical part of Common Arithmetick in Numeration, Addition, Substraction, Multiplication, Division, The Rule of Three (Direct and Inverse,) the Rule of Fellowship (with and without Time), the Rule of False Position, Rules of Practise and Reduction of Coins and some other little things» (Scriba 1970, 26). Wallis explicitly recorded that this kind of mathematics was more common among practitioners than in university circles:

> For Mathematicks, (at that time, with us) were scarce looked upon as Accademical studies, but rather Mechanical; as the business of Traders, Merchants, Seamen, Carpenters, Surveyors of Lands, or the like; and perhaps some Almanak-makers in London. And amongst more than Two hundred Students (at that time) in our College, I do not know of any Two (perhaps not any) who had more of Mathematicks than I, (if so much) which was then but little; And but very few, in that whole University. For the Study of Mathematicks was at that time more cultivated in London than in the Universities (Scriba 1970, 27).

Wallis portrays a society where practical arithmetic had been widely adopted by urban practitioners, and where it was starting to influence the practices of the learned elites. This evidence shows that the 'dramatic transformation' in the levels of numeracy of English society that occurred between 1500 and 1700 (Thomas 1987) was the outcome of a bottom-up process. This bottom-up diffusion started with the adoption of practical arithmetic and of the business techniques of the commercial revolution among English merchants, and subsequently spilled over into new fields, progressively influencing larger subsets of English society.

3. **Conclusion**

We have seen that the first adoption of Hindu-Arabic numerals in both Italian and English vernacular contexts was driven by the emerging need to solve calculations stemming from commercial practices. Among these calculations, particularly important were those relating to practices of exchange, as they implied the need to handle rational numbers – operations which were facilitated by the positional numeral system. The first merchants who adopted these techniques transmitted their knowledge informally. This initial informal circulation of practical knowledge led to an emerging demand for training in practical arithmetic. When this demand became sufficiently strong to sustain a more structured training in practical arithmetic, practical arithmetic schools were founded. These first schools were staffed by specialised masters, who often moved to the new centre from a centre of previous adoption. In turn, practical arithmetic schools acted as accelerators of the social circulation of this practical knowledge, which produced a number of spillover effects in fields beyond commerce.

It is possible to identify these steps in both Italy and England, with England following at a distance of around two centuries. Italian and English schools of practical arithmetic show similar characteristics, and English schools were designed following the model of Netherlandish and French schools, which in turn were distant descendants of Italian abacus schools. The profiles of the mathematical practitioners active in these schools also show similar features. Both in Italy and in England, these mathematical practitioners were lay masters, who taught and wrote in the vernacular, and mainly addressed their works to practitioners. Even if in England quite a few of them were university-trained, neither Italian abacus masters nor English mathematical practitioners were full members of the academic world. These mathematical practitioners conceived mathematics as an inherently applied knowledge. They wrote manuals of practical arithmetic that shared the same fundamental structure and transmitted substantially the same mathematical knowledge.

These similarities are exemplified by a comparison between Paolo dell'Abaco and Robert Recorde. Even though these two figures lived two centuries apart, it is possible to identify a degree of 'kinship' between their works. As discussed in Section 1, Paolo dell'Abaco's *Trattato di tutta l'arte dell'abaco* can be considered as a particularly good source to study the mathematics taught in 14th-century Florentine abacus schools. It covers the fundamentals of practical arithmetic, a wide range of commercial and financial problems, practical geometry, astronomical and calendrical calculations, medicine, and algebra. Considered together, Robert Recorde's works sought to provide a foundation for a new vernacular science in England. Recorde's works covered practical arithmetic (*The Ground of Artes*, 1543), medicine (*The Urinal of Physicke*, 1547), practical geometry (*The Pathway to Knowledge*, 1551), astronomy (*The Castle of Knowledge*, 1556), and algebra (*The Whetstone of Witte*, 1557), often for the first time in the English language. There are clear parallels between the subject matters of these works.

Both Paolo dell'Abaco and Robert Recorde were active as masters of practical arithmetic and as mathematical practitioners. Paolo dell'Abaco advised the commune of Florence on military matters, and Robert Recorde worked in royal mints. Moreover, the works of both authors show the initial spillover of practical arithmetic in fields beyond commerce in their respective societies. Both authors wrote on medicine, astronomy, and measurement, and their research was influential for navigational calculations. While covering a variety of fields, their works consistently give practice a central role in their epistemologies, as both authors were primarily concerned with the practical applications of their knowledge. Despite working at a distance of two centuries, Paolo dell'Abaco's and Robert Recorde's works show a degree of familiarity, as they seem to appear in similar moments of development of their respective societies.

More generally, the evidence provided in this paper shows that it is possible to observe a number of analogies between the Italian and the English spread of practical arithmetic in vernacular contexts. While in Italy this process took off in the 13th century, in England it started in the late 15th century. In both cases, this adoption was driven by an emerging need to handle advanced calculations stemming from commercial practices. After their first adoption in commercial practices, practical arithmetic spilled over to other fields, generating changes in wider social contexts. In both cases, these spillovers occurred bottom-up, and became sufficiently widespread to generate considerable cultural and social changes.

The comparative perspective developed in this paper is significant because Italy and England represent, respectively, the early mover and the late adopter in the spread of the body of practical knowledge. While a distance of around two centuries between the adoption of Hindu-Arabic numerals in Italian and English vernacular contexts may seem surprising, this paper has highlighted the complexity of the economic and social phenomena that underpinned the adoption of this mathematics. As we have seen, this transmission occurred through a complex interaction of informal contacts, emerging demand for quantitative skills, migration of skilled people, wider social diffusion, and institutionalisation of knowledge. We have focussed on the early and the late stages in the transmission of this knowledge to highlight the parallels between these phenomena even at the two furthest remote moments of the spread of this practical knowledge.

As we have seen, the adoption of Hindu-Arabic numerals among practitioners opened new avenues for the application of mathematics to a variety of fields. From this perspective, the diffusion of this mathematics provides a proxy to reconstruct the spread of a wider body of practical knowledge that was incrementally transmitted from the Mediterranean context to the north of Europe. The parallels highlighted in this paper raise the hypothesis of conceiving the onset of the little divergence as the final phase of an innovation cycle. This innovation cycle started with the commercial revolution of the 13th century, and was incrementally transmitted to the rest of Europe. This, in turn, opens new questions about how the social circulation of this practical knowledge differed between European areas.

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Seiji Horii

Promotion of high-quality textiles by prize competitions during the Enlightenment in Saxony. From raw material to finished product manufacturing

1. Introduction

Many European governments implemented economic policies for introducing advanced «useful knowledge» during and after the Industrial Revolution. Their strategies included: providing bounty, awarding medals, inviting engineers from industrially advanced countries, ordering overseas dispatch, and establishing patent systems. Researchers often describe them as «innovation-inducing systems». In Saxony, these policies were implemented from the late eighteenth century (Forberger 1958; Schlechte 1958). A significant policy in Saxony was the system of *Preisaufgabe*, or «prize competitions».[1]

Prize competitions encouraged the public to find solutions for industrial, academic, or social issues, and the amount of prize money to be paid to the innovator was announced in advance. Thus, the premise of the prize competitions can be outlined as: «if you achieve something or solve some difficulties by a predetermined deadline, we will pay you the predetermined amount of money».[2]

According to KEI Research Note (2008)[3], prize competitions have been held worldwide from the sixteenth century onwards, in various industrial or academic fields. KEI Research Note (2008) shows examples implemented in the eighteenth century. Their target has ranged from industrial themes to social issues and mathematics. Prize competitions are still held in several fields. For example, Millennium Prize Problems, published by Clay Mathematics Institute in the United States, provides incentives to solve scientific problems. For the textile industry – the driving industry of the Industrial Revolution – prize competitions were established for the invention or introduction of textile machinery since the development of Hargreaves' spinning jenny and Arkwright's water frame.[4]

I will discuss the diffusion of useful knowledge in the latter half of the eighteenth century from the perspective of the textile industry. Discussions about

[1] Previous studies translated «*Preisaufgabe*» to «prize contest» and «prize essay contest». Moreover, «Aufgabe» could have been more appropriately translated as «task» or «assignment», but I chose «competition» to reflect this system's competitive nature.

[2] Specific examples in Saxony are listed in section three.

[3] You can access this research paper on this URL: https://www.keionline.org/book/kei-issuesreport-on-selected-innovation-prizes-and-reward-programs

[4] Prize competitions related to silk or carpet manufacturing were also set according to KEI Research Note (2008). However, this study does not discuss them in detail.

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Referee List (DOI 10.36253/fup_referee_list)
FUP Best Practice in Scholarly Publishing (DOI 10.36253/fup_best_practice)

Seiji Horii, *Promotion of high-quality textiles by prize competitions during the Enlightenment in Saxony. From raw material to finished product manufacturing*, © Author(s), CC BY 4.0, DOI 10.36253/979-12-215-0092-9.07, in Giampiero Nigro (edited by), *L'economia della conoscenza: innovazione, produttività e crescita economica nei secoli XIII-XVIII / The knowledge economy: innovation, productivity and economic growth,13th to 18th century*, pp. 89-114, 2023, published by Firenze University Press, ISBN 979-12-215-0092-9, DOI 10.36253/979-12-215-0092-9

knowledge or technology diffusion in the eighteenth-century textile industry mainly focus on the transmission of methods and machinery for manufacturing textiles, such as the spinning jenny, from England to the continental European countries. However, this study shows the intention to transfer «useful knowledge» and improve the quality of textile products and manufacturing textile machinery via prize competitions held in Saxony. Knowledge dissemination about product quality originated in England, France, Belgium, and other continental European countries, where high-quality textile products had already been manufactured at that time.[5] These products involved textile goods and their raw materials, and the government also promoted the skills of bleaching and dyeing and the establishment of training institutions. In the latter half of the eighteenth century, the knowledge transfer network in the textile industry was already a multilinear network, including several countries, rather than a uni-directional flow (e.g., from England to one continental European country).

2. Textile industry development in Saxony

Kurfürstentum Sachsen, the electorate of Saxony, industrialised relatively early. According to Tilly and Kopsidis (2020), Saxony was «The first German region to achieve the transition from agrarian to an industrial economy several decades earlier than the northern *Rhineland* and *Ruhr* area» (Tilly and Kopsidis 2020, 26). Saxony pioneered the mechanisation of the textile industry, which began in the latter half of the eighteenth century, providing the foundation for industrialisation by promoting mechanisation from the nineteenth century onwards. The process of mechanisation – including the introduction of spinning machines – has been mentioned in numerous previous studies. The policies of the Saxon government, merchants (e.g., Bugenhagen) and famous inventors (e.g., Matthias Frey, Carl Gottlieb Irmscher, Christian Wilhelm Forkel and Johann Gottfried Pfaff) improved productivity or facilitated the introduction of jenny or carding machines (Forberger 1958; Horii 2020).

The textile industry in Saxony was already well established long before industrialisation began. By the turn of the sixteenth century, fustian weaving and dyeing were brought to Saxony. Dyeing flourished in *Erzgebirge* (Ore Mountains); however, the development of the Saxon textile industry was crippled by the Seven Years' War. It took a heavy toll on Saxony, but a series of economic policies under the German scientific, cultural and industrial enlightenment helped to restore the land. It was able to recover relatively quickly from the devastation (Bochmann, Dresler, and

[5] France produced silk, and Belgium produced superior quality bobbin lace in the eighteenth century. European countries took various approaches to replicate Chinese products. According to Suzuki (2006), «by the end of the seventeenth century, silk production in Europe had developed considerably. By the end of the eighteenth century, the silk industry in Europe had reached the level of China in terms of the technology of the manufacturing process» (Suzuki 2006, 301). Moreover, bobbin lace was mainly embroidered in Brussels. The reputation of Brussels lace grew before the end of the seventeenth century, when it was embroidered on various products – including ties, jewels, aprons, dresses – and used in interiors. Even after 1760, Brussels had a high reputation in Europe for its lace (Kraatz 1989).

Tietze 1995, 540). Prize competitions incentivised innovation, thereby contributing to recovery from the war.

Previous studies have drawn the following conclusions about the Saxon textile regions: First, the industry's development differs from region to region even within a single territory. For example, according to Schäfer (2015), the textile industry in Saxony can be divided into the following six districts: (1) the southern *Vogtland* around the city of *Plauen*; (2) northwards from *Reichenbach/Vogtland*, including the *Zwickau* und *Crimmitzschau Werdau* areas; (3) *Chemnitz* and *Glauchau*; (4) *Chemnitz* and the western *Erzgebirge*; (5) the higher ranges of the *Erzgebirge* (lace making and the manufacture of *Posamenten*) and (6) southern *Oberlausitz*. Other textile industry areas were scattered in *Kamenz*, *Bautzen*, *Bischofswerda* and other regions (Schäfer 2015, 117-118). These areas were considered representative of proto-industrialisation, and the foundation for the later industrial age was laid during the eighteenth century. *Erzgebirge* and *Chemnitz* mentioned in (3), (4) and (5) and *Vogtland* mentioned in (1) and (2) were important regions for the textile industry in Saxony.

Second, in the early modern period, the *Erzgebirge* textile industry replaced linen with cotton products, for example, bobbin lace making, embroidery *(Posament)* and ribbon weaving (Karlsch and Schäfer 2006, 20; Tilly and Kopsidis 2020, 29). In *Chemnitz*, in the northern part of the *Erzgebirge*, the manufacture of «high-quality» socks made of cotton began at least in 1728. As early as 1770, cotton weaving and printing spread, and *Chemnitz* later became a centre of calico printing. Many of these products (e.g., canvas, *wallis*, and *piqué*) were copies of fashionable products made in England and France (Kowalski, Matera, and Sokołowicz 2018, 20; Schäfer 2015, 120). Moreover, by the 1780s, *Plauen* and rural areas in *Vogtland* were mainly producing light, thin and «high-quality» cotton products, such as muslin (Kaufhold 1986, 129-31). Although the production of cotton products increased in the latter half of the eighteenth century, the production of traditional textile products, such as linen and wool, did not stop completely. In contrast to the textile regions of southwestern Saxony, the southern part of *Oberlausitz* mainly produced linen until the end of the eighteenth century. Although linen production there stagnated in the late eighteenth century, the linen industry still constituted a large share of Saxon textile goods exports in 1785 (Karlsch and Schäfer 2006, 20-21). Thus, in the eighteenth century, the Saxon textile industry produced a wide variety of textile products, fabrics, socks, and ornaments made of cotton or other raw materials. They produced a range of quality ready-made and decorative items in addition to yarn and cloth.

The textile industry was established in Saxony in the sixteenth century, but it did not always grow steadily during the eighteenth century. Like the other continental European countries, it was significantly affected by the British Industrial Revolution. However, although the influx of British cotton products had already begun in the 1770s, it did not initially threaten the Saxon textile industry. Rather, it provided a positive stimulus – to some degree – in the form of textile varieties and manufacturing methods. From the 1790s the influence grew stronger. Many merchants and the government felt the pressure at that time because the British brought numerous cotton products to the market in *Leipzig*. Moreover, muslin manufactured in *Plauen* faced stringent competition from British products in the *Leipzig* market. The prices of cotton cloth and cotton yarn made in England were 10-30% lower than those of Saxony. Additionally, with the outbreak of the French Revolutionary War, British manufacturers established sales channels in *Hamburg* and *Leipzig*. The textile industry was in a difficult situation between 1793 and 1806. During this period, the competition with England increased, firstly in the production of muslin and then in the middle- and low-quality products (Bein 1884; Crouzet 1964, 577; Oshima 1960, 466-68; Schäfer 2015, 121). Furthermore, from the mid-1780s, countries such as France, Austria and Russia began closing their markets and imposing high tariffs, thereby placing Saxon textile producers in a predicament (Kowalski, Matera, Sokołowicz 2018, 19).

3. Enlightenment and the promotion of industrial development

The Seven Years' War had a significant economic and financial impact and one of the government's main tasks was to restore the predominantly agricultural economy – as well as the mining and textile industries. This series of reforms was called *rétablissement*.

These reforms in Saxony were inspired by the French and English enlightenment (Blaschke 1967, 74-76). The *Kommerzien Deputation*, which had already been established in 1735, was reorganised in a series of reforms as the *Landes-, Ökonomie-, Manufaktur- und Kommerzien Deputation* in April 1764. The Deputation was not given direct command but was responsible for demographic studies, and research into statistics, education, agriculture, forestry, hunting, fishing, commerce, factories, and many other fields (Czok 1989, 288-289).

Immediately after the establishment of the Deputation, the *Leipziger Ökonomischen Sozietät* – one of the leading scientific academies in the continental European countries – was founded, although it lagged the leading examples of European countries[6] (Henderson 1985, 36). The Economic Society played an important role in spreading the spirit of enlightenment and useful knowledge. Its mission was to «promote the common weal» although its contents tended to be diversified (Bödeker 2012, 182). The focus in the early years was on agriculture and livestock, to improve the nutritional status of the civilian population affected by the war. However, three levels were included – natural science (i.e., mineralogy, chemistry, and mechanics), manufacturing, and trade and agriculture (Bödeker 2012, 188).[7]

These two institutions worked together to implement the system of prize competitions. According to Rübberdt (1934), since the founding of the Economic Society in 1764, it had widely published several types of publications, one of which

[6] Before these efforts in Saxony, scientific or economic societies were established in European countries to expand the network of intellectual exchange. For example, in England, the Royal Society of London was founded in 1660; in France, the Royal Academy of Sciences was founded in Paris in 1666 and in Germany, the Academy of Sciences in Berlin was founded in 1700.

[7] «Their activity included promoting industry by providing advanced training, offering prizes and organising exhibitions; supporting existing (or establishing new) charitable institutions; reforming poor relief, rescue services and health education; setting up schools for midwives; and promoting new policies on vaccination programmes. The four main areas were agriculture, trade and industry, policies (domestic and social policy) and education» (Bödeker 2012, 196).

contained the announced prize competitions (Rübberdt 1934, 53-54). Forberger (1958) mentions the prize competitions, but he only describes who would receive the prizes and when and how many prizes would be awarded in individual cases. He indicates that the awarding of money through prize competitions assisted the development of various industries, but the overall picture is vague.

The study of economic societies by Eichler (1978) is the first authentic examination of prize competitions in Saxony. He positions the economic society in the scientific world of eighteenth-century Saxony and mentions the function of prize competitions. Eichler (1978) reconstructs the data on their winners including the promulgation year of the prize competitions, their theme, the amount of the prizes, the year of the prize awarded, and the names, occupations, and residences of the winners (Eichler 1978, 381-86). He cites the *Leipziger Intelligenz-Blatt* as historical material. However, how this table was executed remains unclear, because the prize winners are not mentioned in the document, and no page numbers are given as the source. Nevertheless, his work is cited in subsequent studies of the achievements of Saxon prize winners in this period, and there is no discussion based on other documents (e.g., Czok 1989; Schöne 2001; Stöbe 1996). Bosse (2018) also discusses this economic policy extensively, but the content of achievements could not be discussed due to the limitations of historical material. Accordingly, Horii (2021) discusses the results achieved by the prize competitions based on the primary data. [8]

I build on the discussion by Horii (2021), to examine the intentions of the prize competitions and the question of who was responsible for the transmission of knowledge and technology in the textile industry in the eighteenth century «who achieved». This will elucidate the origins of the inventors and workers who supported industrialisation.

4. Historical materials

I analysed a part of *Landes- Ökonomie- Manufaktur- und Kommerziendeputation*. The unpublished documents are *Verzeichnisse über die nach den Preisaufgaben der Kommerziendeputation,* 1764-1791 (*Verzeichnisse* 1764-1791) and *Verzeichnisse über die nach den Preisaufgaben der Kommerziendeputation zuerkannten Prämiengelder,* 1792-1810 (*Verzeichnisse* 1792-1810), classified as *02. 03, Rechnungslegung der Prämienkasse in 02. Kassen- und Rechnungswesen bei der Deputation.*

These historical materials include a list of prize winners provided by the Deputation and the Economic Society. The information includes the amount of the

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[8] Horii (2021) examined the cases of textile industry-related prizes. The prizes awarded can be classified into the following eight categories: «(1) raw materials supply; (2) spinning process; (3) weaving process; (4) bleaching, dyeing, processing, finishing and the decoration process; (5) manufacturing of ready-made products, which were directly related to production processes; (6) establishment of textile factories; (7) introduction, manufacturing and improvement of machinery; and (8) education» (Horii 2021, 7). Some points in the process leading up to the awarding of the prizes are unclear, such as the difference between the actual amount awarded and the amount stated in the sentences outlining the prize competitions». However, we can ascertain a specific trend in the recipients of the prizes, indicating that many prototypes were submitted in response to the prize competitions.

prize; the occupation, name, and residence of the winners; the type of the prototype; other details and the number of prize competitions.[9] These historical documents contain information on prototypes and awards that have not been examined in previous studies, and they provide clues to clarify the overall picture of the prize competitions (Horii 2021, 4-5). However, some years are not recorded in the archives, 1773-1781, and I cannot necessarily be sure that all cases that led to the awards have been recorded. The awardees are recorded without interruption except for that blank period.

These historical materials are best suited for examining the subject of this paper. It is widely known that many technological and quality improvements were achieved in Saxony during the eighteenth century. The use of these materials makes it clear what the prize competitions were aiming at and who was responsible for the achievements.

5. Prize competitions implemented in Saxony

This section provides an overview of the prize competitions in Saxony in the late eighteenth century. *Kurfürst Friedrich August III.*, Elector of Saxony from 1763 to 1806 (later *Friedrich August I*, King of Saxony, 1806-1827),[10] inherited his father's willingness to support science and the dissemination of knowledge,

> […]to promote agriculture, manufacturing and trade in the Electoral Saxon lands, and thus to encourage the entire food supply (*Nahrungsstandes*), decided to grant certain premiums to those who would excel in one of these areas, decided to have certain premiums handed out to those who would excel in one of these types, consequently set up a revenue fund for this purpose, and ordered *Landes- Ökonomie- Manufaktur- und Kommerzien- Deputations* to bring the prize competitions drafted under the same highest approval […] (*Leizpiger=Intelligenz-Blatt*, 28 *Juli,* 1764, 276-77).

In other words, the prize competitions promulgated in Saxony were designed to promote agriculture, industry and commerce and improve the food supply after the devastation of the Seven Years' War.

[9] Some of them mentioned almost all the items, whereas others did not mention information, such as the winner's occupation.

[10] *Friedrich August I*, King of Saxony, was the second son of *Friedrich Christian.* He was underage when his father died, and he assumed the throne in 1763. His uncle, Prince Franz Xavier, served as his representative. He succeeded with his father's willingness to learn about the production from other regions to rebuild Saxony.

5.1 The number of prize competitions implemented during the eighteenth century

Tab. 1. **Prize competitions promulgated during the eighteenth century**

Promulgation Year	Prototypes Submission Deadline	Number of Promulgations	Number of Promulgations on Textile Industry	Ratio of Textile Industry
1764	Michaelmas, 1764	29	19	65.5%
	Easter, 1765	9	2	22.2%
	St John's Festival, 1765	7	3	42.9%
	Michaelmas, 1765	6	2	33.3%
	deadline not determined	7	1	14.3%
1766	Easter, 1766	6	2	33.3%
	Michaelmas, 1766	5	2	40.0%
	Easter, 1767	3	1	33.3%
	1767-1771	4	0	0%
1767	Easter, 1767	3	1	33.3%
	Michaelmas, 1767	5	0	0%
	Easter, 1768	3	1	33.3%
	Michaelmas, 1768	5	2	40.0%
	1769-1771	3	1	33.3%
1770	Easter, 1770 Michaelmas 1773	23	6	26.1%
	deadline not determined	4	1	25.0%
1778	Michaelmas, 1779	1	1	100%
1782	1782-1785 (Extended until 1788)	26	8	30.8%
1788	1788-1800	58	12	20.7%
	All Years	207	65	31.4%

Source: 1764; *Avertissement, wodurch auf höchsten Befehl Ihro Königlichen Hoheit des Prinzen XAVERII, Königl. Prinzens in Pohlen und Litthauen u. auch der Chur Sachsen Administratoris, zur Aufmunterung des Nahrungs=Standes sowohl einige bereits unterm 18ten Julii 1764 anderweit ausgesetzte Preiß=Aufgaben, mit einiger Erläuterung als auch einige neue Aufgaben bekannt gemacht werden (Avertissement)*, 1-16, 1766, 1767, 1770, 1778, 1782; *Verzeichnisse*, 1764-1791, 3, 9, 13-14, 19-21, 32-35, 1788; P*reiß=Aufgaben, so auf Höchsten Befehl Ihro Churfürstl. Durchl. zu Sachsen zur Aufmunterung des Nahrungsstandes auf das gegenwärtige, und die folgenden J*ahre 1789, 1790 und 1791 ausg*esetzt worden sind, und von Er. Churfürstl. Landes = Oekonomie = Manufaktur = und Commercien = Deputation bekannt gemacht werden.(Preiß=Aufgaben)*, 4-20.

Consequently, the first prize competition in Saxony started in 1764. The prize competitions were not static throughout the late eighteenth century but were updated occasionally. New prize competitions were promulgated seven times: 1764, 1766, 1767, 1770, 1778,[11] 1782, and 1788 – the last remaining valid until 1800.[12] According to Table 1, 207 prize competitions were valid from 1764 to 1800.[13] Their contents ranged from agriculture to mining, and the textile industry accounted for 31.4% of all assignments. This shows that the Deputation and Economic Society regarded the textile industry as one of the most important targets for promoting development.

The prize competitions in Michaelmas 1764 were the most frequent throughout the early part of the period. The textile industry accounted for 65.5%, which means that it was prioritised by the Saxon government for industrial development in the early stages. After that, there were fewer prize competitions until 1767. Nevertheless, a certain number were related to the textile industry. More than 20 prize competitions were promulgated in 1770, and the largest number (58 prize competitions) was promulgated in 1788. Of these, the textile industry accounted for 20-30%.

5.2 Overview of each prize competition

I undertook a textual analysis of each sentence outlining the prize competitions. I tabulated: the deadline, prize number, raw material, the distinction between the domestic or foreign origin of the raw material, the manufacturing process, product name and prize amount.[14] The 1764 prize competitions included that information (Table 2). Most raw materials mentioned were wool or linen, with camel hair, silk and nettle being the exceptions. No. 6's wool was specified to be made from foreign raw materials, and the rest – wool and camel hair – had to be made from domestic raw materials.[15] In the case of wool, many processes, such as shearing, brushing, spinning, weaving, fulling, dyeing and finishing, were included. Linen processing included: harvesting raw materials, spinning, and weaving.

[11] A special prize competition on dyeing was set in 1778 for one subject only. A reward of 100 Tales was to be paid for submissions relating to red dyeing on exquisite pale burlap or cotton cloth, not yet known at this time (*Verzeichnisse* 1764-1791, 31).

[12] Forberger (1958) said that the prize competitions were published on 18 July 1764, 1 May 1765, 8 February 1766, 28 March 1767, 13 January 1770, 5 June 1782, 13 August 1788, 26 February 1800, 31 December 1805, 14 October 1816, 22 February 1820, and 12 May 1826 (Forberger 1958, 244). The prize competitions promulgated on 1 May 1765 cannot be confirmed in historical materials.

[13] There were three divisions of economic development in Saxony: «the first emphasising developments in the eighteenth century up to the French, or Napoleonic era; the second covering the French period (1792-1815) and the third from Saxon industrialisation up to about 1840 or 1850» (Tilly and Kopsidis 2020, 26). Considering this division of time, we selected the prize competitions in the late eighteenth century before the French influence.

[14] In addition to such information, detailed conditions and other information were sometimes attached. I have provided an overview as there is insufficient space to include all the detail.

[15] As reported in the table, no raw material was specified in many cases, or no distinction was made between domestic and foreign products.

Tab. 2. **Overview of the 1764 prize competition**

Prototypes Submission Deadline	No.	Raw Material	Domestic or Foreign Materials	Manufacturing Process	Product Name	Prize (*Taler*)
Michaelmas, 1764	1	wool	Domestic	shearing	*Landwolle*	60
	2	wool	Domestic	shearing	*Landwolle*	60
	3	wool		spinning	*Garn*	20, 20
	4	linen		spinning	*Garn*	20
	5	wool	Domestic	weaving	*Tuch*	80
	6	wool	Domestic or Foreign	spinning, processing, fulling, dyeing, finishing	*Tuch*	100
	7	camel hair	Domestic	weaving	*Camelott*	50
	8	wool		spinning, weaving, dyeing, finishing, defining	*Zeug*	15, 10, 5
	9	silk		weaving	*Zeug*	20
	10	nettle		weaving	*Nesseltuch*	20
	11	linen		weaving	*Leinwand*	15, 10, 5
	12			weaving	*Zwillich*	15, 10, 5
	13	linen		weaving	*Damast*	15, 10, 5
	14			bleaching	-	100
	15			weaving	*Kammertuch, Batist*	50
	16			spinning	*Garn*	10
	17		Domestic	twisting	*Lotzwirn*	30
	18			twisting, bleaching	*Zwirn*	25
	19			lacemaking	*Spitzen*	50
Easter, 1765	3	wool		brushing, spinning	*Garn*	10
	4			spinning	*Gespinst*	50
St John's Festival, 1765	4	wool	Domestic	shearing	*Wolle*	50
	5			fulling, finishing	*Walk, Fullererde*	30
	6			final product	*Hut*	30
Michaelmas, 1765	5	linen	Domestic	harvesting raw materials	*Flachsbau*	50
	6	wool	Domestic	shearing	*Wolle*	50
deadline not determined	7		Foreign(?)	socks knitting	*Strumpf Würker Stuhl*	30

Source: *Avertissement*, 1-16.

Although no raw materials were specified, bleaching, lacemaking and twisting were also included, and processes other than simple spinning and weaving were incorporated into the list of processes to be promoted. Additionally, prize competitions were allocated for the manufacture of ready-made goods (e.g., hats and socks) and the search for raw materials for fulling. In this way, the 1764 prize competitions were aimed at various processes and products.

Some of the 1766 and 1767 prize competitions were similar in content to Tables 3 and 4. Almost all of them share the same contents: the production of *Zeug*[16] by weaving silk, the harvesting of linen and domestic wool and the production of cambric (*Kammertuch*) and batiste. In 1766 twisting of *Lotwzirn*, and in 1767, fulling was identified as separate items. The number of prize competitions in these years was less than in 1764, and they did not seem to be actively pursued as an economic strategy.

Tab. 3. O**verview of the 1766 prize competition**

Prototypes Submission Deadline	No.	Raw Material	Domestic or Foreign Materials	Manufacturing Process	Product Name	Prize (*Taler*)
Easter, 1766	3	silk		weaving	*Zeug*	20
	5		Domestic	twisting	*Lotwzirn*	30
Michaelmas, 1766	3	wool	Domestic	shearing	*Wolle*	50
	4			weaving	*Kammer-tuch, Batist*	50
Easter, 1767	1	linen		harvesting raw materials	*Flach*	30
1767–1771		not set on the textile industry				

Source: *Verzeichnisse* 1764-1791, 9.

[16] *Zeug* is a small, narrow, borderless fabric made from long wool, with little or no felting, whereas *Tuch* is a felted fabric. While *Zeug* has no precise definition, it seems to be distinguished from *Tuch* on three aspects: small width, unfilled and use of worsted yarn (Morota 1962, 262).

Tab. 4. **overview of the 1767 prize competition**

Prototypes Submission Deadline	No.	Raw Material	Domestic or Foreign Materials	Manufacturing Process	Product Name	Prize (*Taler*)
Easter, 1767	1	linen		harvesting raw materials	*Flach*	30
Michaelis, 1767		not set on the textile industry				
Easter, 1768	2			fulling, finishing	*Walk, Fullererde*	30
Michaelmas, 1768	2	wool	Domestic	shearing	*Wolle*	100
	5			weaving	*Kammer-tuch, Batist*	50
1769-1771	1	silk		weaving	*Zeug*	20

Source: *Verzeichnisse* 1764-1791, 13-14.

Tab. 5. **Overview of the 1770 prize competition**

Prototypes Submission Deadline	No.	Raw Material	Domestic or Foreign Materials	Manufacturing Process	Product Name	Prize (*Taler*)
Easter, 1770 - Michaelmas, 1773	3	wool, cotton, linen		dyeing	*wollenen, baum-wollenen, und lei-nenen Waren*	10
	6	wool		dyeing	*Strumpf*	25
	9	cannabis	Domestic	harvesting raw materials	*Hanf*	30
	10		Domestic	dyeing	*Färberrote*	5
	13	linen		bleaching	*Leinwand*	50
	16	linen		harvesting raw materials	*Flach*	20, 15, 10
	20	silk		harvesting raw materials	*Maulbeerbaum*	50, 30, 20
submit any time until Michaelis, 1773	2	wool, cotton, linen		spinning, weav-ing, dyeing, fin-ishing, designing	*wollenen, baum-wollenen, und leinenen Wa-ren*	billing

Source: *Verzeichnisse* 1764-1791, 19-21.

Table 5 shows that the 1770 prize competitions did not have numerous entries, but significant changes exist in the content outlining them. First, cotton was identified as a raw material for the first time. After the Industrial Revolution, even before the influx of large quantities of cotton products, the importance of cotton production and processing in Saxony was recognised. In addition, four competitions for dyeing wool, cotton, or linen were established. The necessity of high-quality dyeing in the textile industry was also recognised. Furthermore, the harvesting of silk raw material – sericulture and the cultivation of mulberry trees to feed the silkworms – were also added to the prize competition list. Wool spinning and weaving, and the harvesting of raw materials (linen and hemp), were also established.

As demonstrated in Table 6, there were no notable changes in the types of prize competitions and most were the same as in the previous ones in 1782. The manufacturing process included: raw materials harvesting, spinning, weaving, fulling, bleaching, dyeing, and finishing. However, preparing, drawing, and silk threading were added to the list, meaning that the targeted processes diversified. It is also noteworthy that when silk was used as raw material, work related to sericulture and silk threading itself was required.

Tab. 6. **Overview of the 1782 prize competition**

No.	Raw Material	Domestic or Foreign Materials	Manufacturing Process	Product Name	Prize (*Taler*)
3			socks knitting	*Strumpf Würger Stuhl*	30
8			fulling, finishing	*Walker Erde*	30
10	wool, cotton, linen		spinning, weaving, dyeing, preparing, drawing	*wollenen, baumwollenen, und leinenen Waren*	10-50
16	linen, cannabis		harvesting raw materials	*Flach, Hanf*	20, 30, 40
18	wool	Domestic	spinning	*Garn*	100, 200
19			bleaching		50
25	silk		harvesting raw materials, threading	*Maulbeerbaum Seide*	50
26	silk		harvesting raw materials	*Maulbeerbaum, Seiden Kultur*	12 *grossen*

Source: *Verzeichnisse* 1764-1791, 32-35

Finally, Table 7 provides an overview of the prize competitions published in 1788. First, four prize competitions were independently related to silk production. They included the cultivation of mulberry trees and hedges, sericulture, and silk threading. In Europe, the soil and climate are not suitable for growing mulberry trees, and despite efforts in various European countries, there was a history of failed trials (Tsurui et al., 2010, 15). These silk-related prize competitions were part of these efforts. Additionally, there were two bleaching prizes – for cotton and linen. Moreover, a prize competition was held to innovate new products across various processes, such as No. 41, which had been submitted since 1782. Three prize competitions were conducted for spinning, sock knitting and the manufacturing of *Stuhl*.

Tab. 7. **Overview of the 1788 prize competition**

No.	Raw Material	Domestic or Foreign Materials	Manufacturing Process	Product Name	Prize (*Taler*)
34	silk		harvesting raw materials	*Maulbeerbaum*	50, 30, 20
35	silk		harvesting raw materials, threading	*Seide*	12 *grossen*
36	silk		harvesting raw materials	*Maulbeerbaum*	20
37	silk		harvesting raw materials	*Maulbeerheck*	20
38	wool	Domestic	spinning	*Garn*	100, 200
39			spinning	*Garn*	30, 20, 10
40			spinning	*Garn*	several
41	wool, cotton, linen, silk		spinning, weaving, dyeing, preparing, drawing	*wollenen, baumwollenen, leinenen, und seidene Waren*	10-50
42	cotton		bleaching	*Bleichanlage*	50-100 *grossen*
43	linen		bleaching	*Leinwand*	50
44			socks knitting	*Strumpfwürker Stuhl*	30
45				*Stuhl*	15, 20, 30, 40

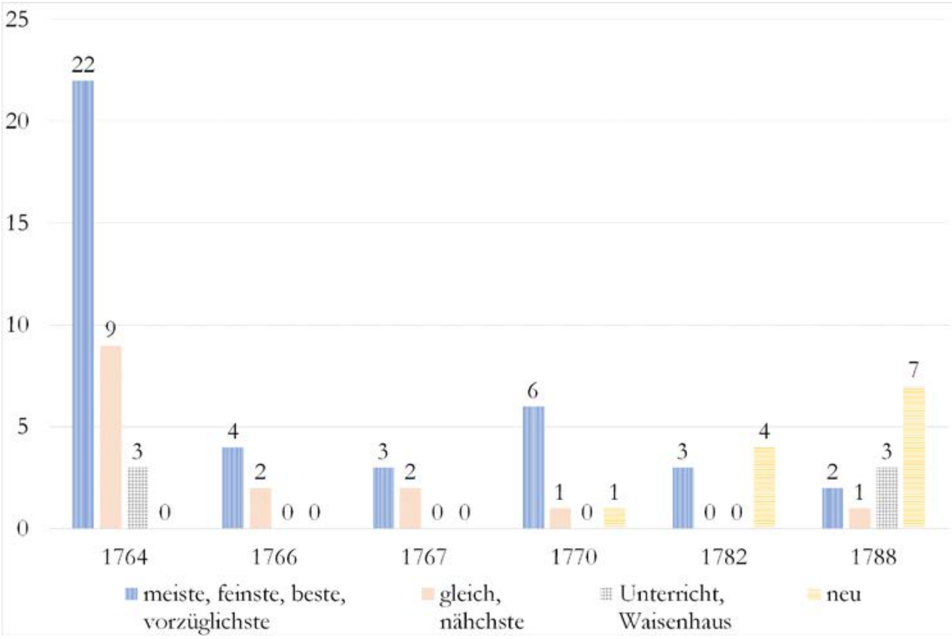
Source: *Preiß=Aufgaben*, 14-17.

The amount of the prize varied, so my analysis did not identify a trend. Nevertheless, most of the prizes amounted to 10 *Taler* or more. Considering that the weekly salary of a weaver at that time was 1 to 2 *Taler* (Oshima 1960, 457), the prizes represented more than the average monthly salary of a weaver. Hence, some of the prize competitions, especially the ones above 100 *Taler*, were very motivating for the entrants.

6. Textual analysis of primary documents: what were the intentions?

I have clarified the characteristics of prize competitions from the viewpoint of aspects of production in the textile industry – such as raw materials and processes – and followed this with a detailed textual analysis of the sentences outlining the prize competitions to discover the intentions. I extracted the frequently used terms from the sentences describing the prize competitions.[17] These enabled the exhibitors to understand the criteria on which the prizes would be awarded. The following words were frequently found: (1) *meiste, feinste, beste, vorzüglichste*; (2) *gleich, nähchste*; (3) *Unterricht, Weisenhaus* and (4) *neu*.[18] (see Graph 1).

Graph 1. **Frequently used terms outlining the prize competitions**



Source: *Verzeichnisse* 1764-1791, *Preiß=Aufgaben*.

6.1 Textual analysis (1): best prototypes

Collectively, (1) was intended to award prizes to the «best» prototypes. In the 1764, 1766 and 1770 prize competitions, phrase (1) was found in more than 80% of the setting sentences; in 1767, the same phrase was found in three of five settings related to the textile industry. In the 1782 and 1788 prize competitions, the number of (1) phrases decreased, but they were still present to some extent. Such expres-

[17] This refers to keywords or criteria for awarding the prize and excludes commonly used conjunctions, articles, and pronouns, such as *und* («and» in English), *die* («the» in English) or *er* («he» in English).

[18] These words translate into English as (1) most, finest, best, most exquisite; (2) equal; (3) education, orphanage, (4) new. The same word is not always used in different prize competitions. For example, *gleich* and *nähest* have different meanings, but the intention is the same (that is, to make the product equivalent to other regions).

sions were not limited to the prize competitions, but were a common feature in innovation-inducing systems.

6.2 Textual analysis (2): an equivalent quality to foreign products

Meanwhile, (2) reflects the frequently used terms of the Saxon prize competitions in the late eighteenth century. These expressions indicated that prizes would be awarded to those who could produce prototypes of «an equivalent quality to foreign products». This is evident in the following examples from the relevant parts of the prize competitions in Michaelmas 1764:

> No. 6. Whoever exhibits […] cloth that is equivalent to English or French cloth in fineness and quality […] No. 7. Whoever exhibits fine domestic camlet […]closest to the French, Brussels, and Leiden camlet in quality […] No. 9. […] for the most exquisite piece […] of the various silk cloth, which comes closest to the French […] No. 14. Whoever proves […] that he can bleach the goods as well as they bleach in Harlem or comes closest to the way they bleach there […] No. 17. Whoever produces the finest *Lotzwir*n […] which is equal to the Dutch one […] No. 19. Whoever has a piece of lace […] equal to Brussels manufactured […] (*Avertissement*, 1-16).

In Easter 1765 No. 3 and Midsummer (St John) 1765 No. 5 and 6:

> No. 3. they have carded the wool […] in the Dutch way […] No. 5. Whoever discovers a quantity of fulling or fuller's earth in the country that is equivalent to the English […] No. 6. For the hat that comes closest to the finest English in all qualities […] (*Avertissement*, 1-16).

The 1766 prize competitions No.3 and 5 and the 1767 prize competitions No. 2 and 1, contained two expressions (2) each:

> No. 3. […] for the most exquisite piece […] of the various silk, which comes closest to the French […] No. 5. Whoever produces the finest unbleached *Lotwzirn* […] which is equal to the Dutch […] No. 2. […] has found it to be equal to the English […] No. 1. […] for the most exquisite piece […] of the various silk cloth, which comes closest to the French […] (*Verzeichnisse* 1764-1791, 9, 13-14).

After this, in the wording of the prize competitions promulgated in 1770, expressions like (2) were rarely used. The 1770 prize competitions No. 9 and 1788 No. 43 were an exception:

> No. 9. Whoever in Thuringia knows how to prepare the cannabis harvested there as finely and as well as the *Rhenish* […] (*Verzeichnisse* 1764-1791, 32-35).

> No. 43. Whoever can bleach […] and thus comes closest to the foreign bleaches […] (*Preiß=Aufgaben*, 14-17).

However, No. 9 implied that it was not made in a foreign country but manufactured in another territorial state, and No. 43 does not have a specific foreign country's name.

The prize competitions classified as (2) often referred to specific foreign countries, where the people engaged in the textile industry manufactured the most illustrious products or used the most advanced technology in Europe. For instance, the prize competitions that mention silk were prize No. 9, (Michaelmas 1764), prize No.3, (Easter 1766) and prize No. 1, (between 1769 and 1771). Their purposes were to produce silk fabrics of the same quality as French silk fabrics. Silk products of high quality were well established, especially in China. Subsequently, by the end of the eighteenth century, the silk industry in Europe had reached a level comparable with that of China in terms of manufacturing process technology (Suzuki 2006, 301). Italy and France were the centres of this industry.[19]

6.3 Textual analysis (3): educational intentions

The educational prize competitions categorised in (3) were established in 1764 and 1788. In the 1764 prize competitions, the administrators were incentivised to train children living in some orphanages to produce twisted yarn or spin. A modern view is that this practice represents servitude, not education, but at the time it was regarded as training in a useful skill, so the word 'educational' applies. The Easter prize competitions in 1765 featured similar elements, promising a prize to the schoolteacher who taught the children how to make twisted yarn after school. However, the 1788 prize competitions had a more overtly 'educational' intent. In other words, No. 39 aimed at establishing a spinning school in an area where spinning mills did not exist, expanding the textile industry and securing workers with a certain level of skill. The 1788 prize competitions No. 38 and No. 40 were not directly 'educational' in intent. They sought to introduce the skill of spinning in «lands where it has never been common to engage in spinning».

[19] Another example is camlet. It is mentioned in prize No. 7 of the Michaelmas prize competition in 1764. In the eighteenth century, camlet was mainly produced in England, France, Netherlands, and Flanders. In fact, in the prize competitions, products made in France, Brussels and Leiden were considered the quality standards to be replicated. Furthermore, it was expected that the products would be manufactured at the same level as the main production areas by the Deputation and Economic Society. The prize No. 19 in Michaelmas 1764, called for the manufacture of lace of the same quality as Brussels lace. The lace embroidered in Brussels was of a type called bobbin lace. In the late seventeenth century, the reputation of Brussels lace began to rise, and it was embroidered on a wide variety of items (e.g., neckties, jupes, aprons, dresses, and interior decorations). After 1760, Brussels lace was still popular in Europe. In 1760 and later, Brussels lace was still in use in Europe, and the lace was highly valued (Kraatz 1989, 90). The competition organizers were sensitive to the market demand and the need to produce lace of high value.

6.4 Textual analysis (4): novelty

Finally, the word *neu* began to appear for the first time in 1770. This expression was first identified in the prize competitions promulgated in 1770. In this way, prize competitions for «novelty» in the textile industry began to be established. More than half of the prize competitions promulgated in 1782 and 1788 contained keywords related to (4). From this, I understand that the intention was to supply the market with abundant goods by widely seeking textile products that had not previously been manufactured in Saxony.

Prize competitions often try to award prizes to the most outstanding submitted prototypes. Additionally, in the 1760s and 1770s, when prize competitions were first implemented, product quality was required to be equivalent to that of foreign countries. However, after the 1780s, the authority mainly demanded «novelty». This may have been in consideration of the changes in the circumstances of the textile industry discussed in Sections 2 and 3. Unfortunately, the real changes in policy intentions cannot be easily captured because how these sentences were developed by the Deputation and the Economic Society is unclear from the existing historical documents. Nevertheless, the demand for high-quality products from abroad and the attempt to provide spinning training are specific characteristics of Saxony's prize competitions.

7. Who were the achievers?

I analyse who the achievers were, how the achievements were accomplished, and what the implications are, based on primary historical documents.

First, I examine the general trend. It is noteworthy that in numerous cases, the occupation of prize winners was not mentioned. Table 8 shows that more than half of occupations for 1782 and 1788 had no description or were listed as «unknown». Tables 9 and 10 show that for both the 1782 and 1788 prize competitions, the largest number of respondents whose occupations were unknown was in the field of silk (and half silk). In 1782 and 1788, 56.5% and 32.0%, respectively, of those whose occupation was unknown, were in the silk industry, including silk threading and weaving. Given that the silk industry had not been established in Saxony until the eighteenth century, most of the spinners and weavers who were engaged in the traditional production of wool, linen and cotton would not have entered the costly silk industry. In addition, given the need for pruning skills or growing mulberry trees, many of those whose occupations are not listed are likely to be categorised into the two occupations: gardener and large farm owner.

Tab. 8. **The occupations of the prize winners**

Occupation		1764	1766	1767	1770	1782	1788
factory owner	textile factory owner	4	1	10			1
	socks factory owner					1	1
	band factory owner					1	1
	pile factory owner						1
	lace factory owner						1
machine builder							2
gardener	royal palace gardener					5	20
	gardener						8
large farm owner	large farm owner					2	14
	large silk farmer						1
spinner	spinner *Meister*						1
	spinner	4					
	wool spinner	11					
weaver	weaver *Meister*						2
	weaver	5	1		1	5	31
	linen weaver	1			1	1	1
	cotton weaver					1	
	velvet weaver	1					1
processing process worker	bleacher						2
	dyer				2		
	fulling worker	1					
	Posamentier					1	2
	bobbin lace knitter						1
	Tuchscherer					1	1
socks knitter		3				10	12
cabinetmaker						1	
merchant		2			2		4
educator	educational committee						1
	principal						2
	teacher	1				2	
	school seminarians						1
cleric, pastor							6
public officer, public institution		1			3	18	13
judge					2	1	
book printer		2					
child			1				11
home manager							1
miner							2
supervisor of a sulfur smelter							1
others							2
no description or unknown		21	2	2	5	62	178

Source: *Verzeichnisse* 1764-1791 and *Verzeichnisse* 1792-1810.

Tab. 9. **Awards for unknown occupation - Known raw materials and processes**

	Raw Materials and Processes	1764	1770	1782	1788
Factory	fostering-wool spinning				1
	establishment-wool socks knitting				1
	establishment-band			1	1
Silk	machinery manufacture			1	1
	raw materials		4	14	46
	threading			5	
	weaving			13	6
	printing				1
	decorating (ribbon & lace)				3
	socks knitting				1
Half Silk	weaving				1
	dyeing			1	
	defining			1	
	socks knitting				3
	unknown, others			1	
Linen	machinery manufacture-weaving			1	
	raw materials	3		2	8
	weaving			1	
	bleaching			1	2
	printing				1
	unknown, others				1
Hemp	raw materials				1
Wool	machinery manufacture-worsted	1		2	1
	machinery manufacture-socks knitting				1
	machinery introduction-spinning				1
	spinning	1			
	spinning-firstly produced in the area				1
	weaving	5			
	finishing	1			
	carpet				1
Cotton	machinery manufacture-weaving				1
	machinery introduction-weaving				1
	spinning				1
	spinning-firstly produced in the area				1
	weaving			3	13
	weaving-firstly produced in the area				1
	dyeing	2			2
	printing				1
	socks knitting				5
	new goods				5
	unknown, others			1	
Casimir	machinery manufacture-worsted				1
	printing				1
Typha	socks knitting				1

Source: *Verzeichnisse* 1764-1791 and *Verzeichnisse* 1792-1810.

Tab. 10. **Awards for unknown occupation - Only processes or other information is known**

Processes and Others		1764	1766	1767	1770	1782	1788
Spinning	spinning	1	2	1			2
	machinery introduction						1
	machinery manufacture						2
	machinery improvement						2
Twisting	machinery manufacture					1	1
	twisting					1	
Weaving	weaving	1					3
Worsted	machinery manufacture						2
Fulling	machinery manufacture						1
Bleaching	bleaching	1					3
Finishing	finishing						1
Decorating	machinery introduction-ribbon	5					
	decorating						2
	unknown others				1		
Socks	machinery introduction					10	4
Knitting	machinery manufacture						1
	socks knitting						9
Ready-	dress (silk & wool)					2	
made	vest (cotton & unknown)						2
	gilet						1
	shawl						1
	shirt						1
	skirt						1
	boots						1
	cotton *Beinkleid*						1
	Prinzessin						1
	new goods						7
	drawings						1
Education	spinning & weaving						5
Others	machinery sample						1
	machinery for horse comb						1
Unknown				1		1	3

Source: *Verzeichnisse* 1764-1791 and *Verzeichnisse* 1792-1810.

Second, I discuss the prize winners for whom the occupation was known, based on Table 8. In the 1764 competition, the largest number of prizes was awarded to spinners – especially wool spinners – and the second most common occupation was weavers. Both worked with traditional materials, such as wool and linen. Additionally, the following were engaged in the textile industry: four textile factory owners, three sock knitters and one fulling worker. Meanwhile, two merchants, two book printers, a public officer and a teacher were from professions not normally engaged in the textile industry. Merchants, throughout the period, were responsible for the transport of raw materials and machinery, but they did not directly produce anything.

In the 1766 prize competitions, only three occupations were known: a textile factory owner, a weaver, and a child. In the 1767 prize competitions, ten textile factory owners were awarded prizes, indicating that the prizes were awarded to those who already owned factories. Of these, eight were wool weavers, and again the prize was awarded to those still working with traditional raw materials. These trends seem to have been maintained in the 1770 prize competitions, but dyers and judges[20] were awarded for the first time. Especially, concerning the dyers, this may have corresponded to the four new prize competitions established in 1770.[21]

Corresponding to the changes in the sentences outlining prize competitions examined in Sections 5 and 6, substantial changes also occurred in the attributes of the 1782 and 1788 prize winners. First, awards were given to (royal palace) gardeners and large farm owners, which had not previously been confirmed. They engaged in the silk industry, in aspects such as sericulture and growing mulberry trees. Next were the public officers. For example, in the prize awarded on 28 February 1783, the mayor of *Bautzen* received a prize for setting up a textile factory. However, this was an exception, as most of the public officers were awarded prizes related to the silk industry. Like the merchants, they were awarded prizes for their efforts to spread the breeding of silkworms.

The weavers and sock knitters won many prizes again. As in the 1764 prize competitions, they achieved textile production or sock knitting. The first occupations to be awarded in the 1782 competition were: sock factory owner, band weaving factory owner, cotton weaver, *Posamentier*, *Tuchscherer* and cabinetmaker, and in the 1788 competition: pile factory owner, lace factory owner, machine builders, bleacher, bobbin lace knitters, educational committee member, school principal, student, cleric, pastor, home manager and miner. The occupations – educational committee member, school principal, student, cleric, pastor, home manager and miner – do not seem to be directly related to the textile industry; however, the educational committee members and school principals were involved in the training of spinners and the production of silk-related products; the cleric and pastor supplied raw materials for flax and silk; the home manager presented samples of muslin; and the miner was involved in the establishment of a spinning school for girls, all of which involved silk, education and other achievements not requiring special knowledge.

Moreover, few consistent cross-process awards were given, such as spinners to weaving or dyers to spinning. The Saxon prize competitions did not reflect a policy of encouraging people to change to new professions but incentivised the spreading of useful knowledge in the professions in which they were already engaged (e.g.,

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[20] The judges were not involved in the textile industry but had planted or delivered mulberry trees in silk-related industries.

[21] Dyeing was not an easy task for anyone and required a certain level of skill and knowledge. This may have led to the establishment of a separate prize competition for dyeing in 1778.

manufacturing high-quality products or new products). However, because the establishment of factories and schools in areas where spinning and similar industries had not previously been common was also sought and achieved, it is evident that work in new industries was undertaken in some cases. Even in such cases, those already engaged in the industry established the factories and schools, and the knowledge dissemination in the occupations in which they were already engaged was still an important achievement.

In many cases, the implementation of the prize competitions confirmed the awarding of prizes to occupations such as factory owners, spinners, and weavers, which were directly related to production in the textile industry. However, some prize winners – merchants, book printers and judges – were engaged in the dissemination of silkworm eggs. Strategies such as prize competitions are likely to be considered «innovation-inducing» but this is not always the case when the realized situation is examined at the micro-level. However, it cannot be denied that they have played a role in promoting some industries, for example, silk production.

Third, I consider some of the individuals who received the prizes. Prominent figures in the Saxon textile industry who introduced or improved textile machinery were M. Frey and C.G. Irmascher. J.G. Pfaff and C.W. Forkel succeeded in replicating and improving carding machines. They received large sums of money from the Saxon government for their work. J.G. Pfaff received a prize for his carding machine on 30 June 1787 through prize competitions, as did C.W. Forkel for his wool carding machine and flax loom on 31 December 1787. However, M. Frey and C.G. Irmscher were never awarded. In addition, Johann Georg Esche – who worked in the sock knitting industry in Saxony during the eighteenth century and laid the foundations for the leading sock manufacturers in Saxony – was not mentioned in any sock knitting award. In other words, most of the awards through prize competitions were given to people who were not considered the most important figures in the history of the development of the textile industry.

8. Conclusion: intentions and achievements

In Saxony, the traditional textile industries were established from the sixteenth century, but the ravages of the Seven Years' War devastated the territory, threatened the people's livelihoods, and damaged numerous industries. Coincidentally, the enlightenment was gaining ground in Germany and the Electorate and Saxon government implemented an industrial enlightenment-based policy. A series of reforms and economic policies were proposed after the Seven Years' War. The British Industrial Revolution also influenced these strategies, which included prize competitions.

The prize competitions in Saxony in the second half of the eighteenth century, with its specific intentions – reflected in the demand for «high-quality» or comparable products to those of foreign producers and the establishment of training institutions – had as its main objectives the production of high-quality products and the dissemination of knowledge. The implementation of this policy could have resulted in the production of «high-quality» products in various industries but some researchers thought that improving the quality of textile goods at the beginning of industrialisation or introducing machinery in economically disadvantaged countries was not so difficult. However, as Schäfer (2015) mentions, it is «easier said than done». The government needed to properly assess the situation of the country when implementing a prize competition or any policy, using the principles of the industrial enlightenment. The policy can only find its economic significance when a certain intellectual base in the industry – the existence of workers – is already established. Thus, to investigate knowledge diffusion I will need to attend to «knowledge acceptance».

Numerous points still need to be discussed. First, it is unclear what policy-making process was used to decide on prize competitions. One of the main tasks of the Deputation was to establish the prize competitions but they were also tasked to gather economic information about Saxony and other European countries. They collected information on the devastation caused by the war in Saxony, the influx of British goods, demographics, education and much more. Whether this information was considered in the formulation of the prize competitions and if so, how, is a subject for further investigation. Circumstantial evidence and several previous studies indicate that Saxony's economic stability is evidence that the textile industry must have been supported. This corroborative work will help to clarify the activities of the Deputation.

Second, whether the products, which led to the prize award, were of «high quality» or «equivalent to foreign products» must be examined. I find the following evidence in the prize competition of Easter 1768:

> However, after the trials were conducted, the results were not such that the premium could have been awarded to anyone in accordance with the prescribed requisites: This premium is hereby once again awarded […] (*Verzeichnisse* 1764-1791, 13).

In other words, the Deputation did not award a prize for a prototype that did not meet the criteria. The Deputation conducted an inspection and awarded money to those who maintained a certain level of quality. How this inspection process was conducted is not known.[22] Determining what led to the evaluation of the quality of the prototypes as «high-quality» or «equivalent to foreign products» will enable us to evaluate the results of the prize competitions.

Thus, I cannot conclude that the Saxon prize competitions were an essential economic strategy for developing the textile industry or a policy to form the basis for nineteenth-century industrialisation. I can conclude that the prize competitions aimed to promote the textile industry – the main industry in Saxony – by improving the quality of existing products to be equivalent to those of foreign countries, by incentivising the manufacture of new products and by disseminating knowledge. It

[22] For example, the spinning machines were possibly inspected by foreigners who had already been invited or by leading merchants in Saxony. In fact, when the spinning jenny was introduced, submitted drawings and products were carefully inspected (Horii 2020).

was a successful policy, especially from the 1780s onwards, when the development of human resources for the textile industry was a focus.

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Heinrich Lang

*«Li vostri che tenghono li libri non sanno tenere tanti chonnti» Useful knowledge and accounting as seen through the accountant's lenses and the logic of capitalism**

1. Introduction

On 6 December 1518, the Florentine Lionardo Spina, the director of the Salviati-company in Lyon, wrote a letter to Bartholomäus Welser & Mitverwandte and refers to some transactions operated during the previous fairs. In the same context he reviews the accounting techniques employed by his fellow merchant bankers from Augsburg:

> […] we understood that your men who keep the books do not know how to keep accounts, in the future we should make it one or two accounts, as you say, however, in some cases you could not do it in another way, because those accounts are accounts of different things.[1]

This quotation is one of the very few occasions when we learn about the transfer of accounting techniques explicitly. In this case, the manager of an enterprise of high profile, Lionardo Spina, explains to the bookkeeper of the Welser company how accounts should be kept. Also Bartholomäus Welser & Mitverwandte was one of the great players of that day. Spina knew from the letters he received that the Welsers, up to a certain point at least, did not distinguish into various accounts what actually should be put in different accounts. Hence, we may observe an apparently one-way transfer of a more complex understanding of accounting from a Florentine merchant banker to a South German business friend.[2]

Despite this illuminating individual case, it remains an open question how accounting techniques travelled and were transferred from one cultural context to another or just even from one firm to another, and how the accounting practices of

* I am very grateful to my friends and colleagues Richard Goldthwaite (Florence), Federico D'Onofrio (Vienna), Christof Jeggle (Bamberg), and Markus A. Denzel (Leipzig) for their help and advice to this article. Thanks also to the international working group Knowledge and Economy.

[1] Scuola Normale Superiore di Pisa (SNS), *Archivio Salviati*, *I*, 472, c. 8v: «[…] abiamo inteso che li v(ost)rj che tenghono li lib(r)j no(n) sanno tennere tanttj chonntj, p(er) l'avenire si farà uno/ o /ij chontj chome djtte, ma qualche volta no(n) si può fare alt(r)imenttj p(er)ché atenghonno a djversa».

[2] For the Salviati companies in Lyon: Matringe 2016; Pallini-Martin 2018; Lang 2020. For the Welser companies: Häberlein/Burckhardt 2002; Lang 2021.

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Referee List (DOI 10.36253/fup_referee_list)
FUP Best Practice in Scholarly Publishing (DOI 10.36253/fup_best_practice)

Heinrich Lang, *«Li vostri che tenghono li libri non sanno tenere tanti chonnti». Useful knowledge and accounting as seen through the accountant's lenses and the logic of capitalism*, © Author(s), CC BY 4.0, DOI 10.36253/979-12-215-0092-9.08, in Giampiero Nigro (edited by), *L'economia della conoscenza: innovazione, produttività e crescita economica nei secoli XIII-XVIII / The knowledge economy: innovation, productivity and economic growth, 13th to 18th century*, pp. 115-135, 2023, published by Firenze University Press, ISBN 979-12-215-0092-9, DOI 10.36253/979-12-215-0092-9

one bookkeeper influenced the accounting practices of another. Knowledge of accounting was fairly practical knowledge which scarcely was explicitly mentioned when put into use. At the mean time it had become an almost natural technique of calculation.

If letters or sheets of notices do not tell, we have to dig deeply into account books to shed light on the mere transfers or, in a more profound understanding, the genealogy of accounting practices. For Italy we have especially in the Venetian context manuals on accounting at hands, but in Tuscany either none has survived or none had ever been written.[3]

However, it was the bookkeepers that disposed of this practical knowledge. My hypothesis here is that in Renaissance Florence of the late fifteenth to early sixteenth century the figure of the accountant-expert emerged. Although we are talking about a very tiny group of bookkeepers which kept accounts for others, it was a significant and exemplary move forward in the history of accounting. The said men managed the personal accounting for the complex transactions on the merchant bankers' behalf. This also means that these particular bookkeepers acquainted a highly evolved knowledge of accounting and, thus, became experts. Therefore, I will refer to the case study of Matteo Brandolini who became the accountant-expert of Alamanno Salviati (1510-1571), son of the papal banker Iacopo Salviati.

This paper discusses the passage from bookkeeper to accountant-expert. The practices of accounting though will be depicted on the background of knowledge of accounting, because the essential question is: how did the newly emerging accounting-expert get acquainted with the expertise of accounting?

The 'bookkeeper' could be defined in a narrow sense simply as the person which keeps the accounts of someone in everyday operations. We use the term in a very general view as well. The 'accountant' in a broader understanding is a person which still does the work of a bookkeeper, but more on an expert level by interpreting the accounting techniques and their adoption to complex banking operations. Both terms are not taken from the evidence[4].

In consequence, the following considers useful knowledge in the accounting perspective during the late fifteenth and sixteenth centuries. Thus, 'useful knowledge' will be addressed as 'practical knowledge of accounting'. The point of depart is the term 'useful knowledge' as brought into debate by Simon Kuznets and, later on, by Joel Mokyr. However, that kind of knowledge refers to the era of academies in the eighteenth century. This is not the case with knowledge of accounting which is discussed here, because in the centuries earlier knowledge of accounting was not subject to academic, but to vocational education and training on-the-job.

The use of practical knowledge of accounting leads to a crucial issue of accounting practices and, hence, to the inquiry of who used knowledge of accounting and in which contexts it was employed. The answer to these questions is rather simple: in

[3] On the 'management' of practical knowledge and accounting as an 'instrument of resiliencing' recently: Denzel 2020, 51-59.

[4] The difference between 'bookkeeper' and 'accountant' is somewhat artificial. In modern vocabulary of job descriptions we are told that the bookkeeper is involved in day-to-day business of accounting, while the accountant's service is the interpretation of accountancy. I am using the English terms to raise the profile of the 'new type' of bookkeeper and to stress my hypothesis.

the first line it was the bookkeeper. But this answer rises another series of questions following-up. The bookkeeper had to be trained with accounting techniques and developed his own set of practices by keeping accounts of the firm, of the institution, of the household or of himself (Goldthwaite 2015).

Only in some exceptional cases bookkeepers like Matthäus Schwarz (1497-1575), the «Hauptbuchhalter» (the bookkeeper of the central ledger) of the patrons Jacob and Anton Fugger, became truly visible. For instance, Matthäus Schwarz is presented at the desk sitting next to Jacob Fugger in the headquarters of the Fugger company (the «Goldene Stube») as shown in the famous «Trachtenbuch." Furthermore, he is the author of various manuals on bookkeeping like the «Musterbuchhaltung» and the «Kaufmannsnotizbuch."[5]

In general, the bookkeeper is *the* neglected feature of accounting history though. The development of accounting techniques mainly is regarded from the account book's point of view, particularly when the appearance of the Double Entry Bookkeeping is discussed. In these cases, the bookkeeper remains an almost 'anonymous' entity whose contribution to accounting techniques is given for granted, but never carefully elaborated.[6]

Particularly Italian archives preserve fragments of accounting and account books that originate from the times since the Commercial Revolution. In that context, the bookkeeper does not emerge as an independent figure in the process of accounting and developing of accounting techniques. He is only referred to as bookkeeper in his function of keeping books. The Tuscans called him «the one who holds the books» («tenere i libri»). The perspective on the development of accounting techniques is focussed on the merchant banker himself and the manager which is the junior socio (the minor shareholder) of the company «for the estimation of his person» («per la stima di sua persona») as the contracts spell it out (Goldthwaite 2007; De Roover 1963a).

At the core of the following is a particular character of bookkeeper and his knowledge of accounting: the personal accountant which evolved in the late fifteenth and early sixteenth centuries. Due to the complexity of business operations and forms of investment, the set of accounts diversified and, hence, the range of processes a bookkeeper was involved in multiplied. In running commerce and banking the main bookkeeper is the one which keeps the ledgers of the business partnership. In most cases, the 'director' of the company was also the key figure of the accountability of the firm. Still, the the position and agency of the bookkeeper within the management fades out behind the analyses of accounts (Denzel 2020; Goldthwaite 2018).[7]

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[5] The *Trachtenbuch* of Matthäus Schwarz is preserved in the Niedersächsische Landesbibliothek, Hannover, and accessible online: https://commons.wikimedia.org/wiki/File:Trachtenbuch_des_Matthaus_Schwarz_aus_Augsburg,1520_-_1560.PDF?uselang=de (20 November 2022). On Matthäus Schwarz and his visibility: Groebner 1998. Introduction to Matthäus Schwarz and his "Kaufmannsnotizbuch": Westermann and Denzel 2011. On the "Musterbuchhaltung": Weitnauer 1931. For his accounting techniques: Isenmann 2019.

[6] One of the best summaries on the history of accounting techniques is Yamey 1991. The same is true for the history of accounting in Late Medieval Germany: Penndorf 1913.

[7] On complexities in Florentine economy: Padgett and McLean 2006.

The emergence of the accountant becomes evident with the personal bookkeeper of the merchant bankers' personal accounts. This development could also result from social and political changes which evolved in Florence the 1530s, when the Republic ceded to exist and the politically leading group of the merchant bankers was gradually replaced by an elite oriented to the court (Burr Litchfield 1986; Goldthwaite 2009). In this context, we can observe best the shape of the new role which could be described with the particular character of an expert. In the end, personal accounts were kept in the same way as account books of a business company. However, it can thus be hypothesized that the merchant banker himself gave way to his accountant to manage his domestic and personal accounts and hence the new type of the accountant-expert emerged (Goldthwaite 2017).

The following is a contribution to the history of Florentine capitalism. For a better understanding the relevance of knowledge and practical skills of accounting for the capitalist behaviour in the early sixteenth century will be discussed. The South German background of the development of accounting shall create a contrast for comparison. Hence, this article does not deal much with the origin of capitalism in the Florentine Renaissance, but more with the knowledge and skills of accounting as the key issue of accounting history. Capitalism will be treated through the lens of the bookkeeper and the accountant-expert.[8]

2. The concept of 'useful knowledge' and accounting

In a first chapter we should examine the concept of 'useful knowledge' and its impact on accounting. The debate on 'useful knowledge' is still open. When Joel Mokyr introduced 'useful knowledge' as an agent of cultural change which broke path to the concept of economic growth, he referred mainly to technological knowledge (that is knowledge about nature). By that he intended the open-mindedness towards the recognition of nature and its laws which, then, became applicated on processes of production. A key role in this context plays the Enlightenment as far as it left behind religiously motivated moral obstacles and, hence, turned to a new perception of the world. In consequence, the concept of economic growth, which underpins the rise of capitalism, was born as a mind set of secular calculative attitude.[9] In doing so, Joel Mokyr argues that the decisive step forward to capitalism does not derive from the economic development in the European cities in the tenth and eleventh centuries as had been told before.[10]

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[8] Convincingly Francesca Trivellato argues that the comparison of processes of capitalisation on the ground of deeply localised research shifts away from the question of the origin of capitalism and sheds new light on the business history in pre-industrial economies: Trivellato 2020.

[9] Mokyr 2002, 3-26; 339-41. This is a modification of the 'Great Divergence'-hypothesis as exposed by Kenneth Pomeranz some years earlier (2000). Of course, we notice the anti-religious tone of what Joel Mokyr tells us. Since many scholars refer to Joel Mokyr (and to Simon Kuznets) in the context of 'useful knowledge' (like the Settimana di Studi Francesco Datini of the year 2022), I am briefly looking at his main hypothesis, too.

[10] On the Commercial Revolution as an urban project of the High Middle Ages and its meaning for the emergence of capitalism: Lopez 1971; De Roover 1963b.

Some years later, Steven Marks argues instead that the way to capitalism went through the information revolution which took place above all since the seventeenth century. Marks speaks about information circulated within correspondences, journals and newspapers – by paperwork which defused and stored knowledge about market evolution, development of prices, but also technological knowledge.[11]

The result of Mokyr's and Marks' seminal works is not really convincing in the strict sense: The Western European culture of Enlightenment – taken as emancipation from religious obstacles to (re)thinking nature – was at the core of preconditioning the Industrial Revolution. In the last decade a historiographic boom emphasised the relevance of technical knowledge for growth.[12]

All these important statements about knowledge, though, neglect accounting techniques as technological and, hence, practical knowledge ('useful knowledge'), in general. This blindness towards accounting is quite amazing in this context, because in the end it was accounting techniques to measure economic growth – whatever culture we are talking of[13]. This may be the more surprising since one hundred years ago, some scholars like Max Weber or Werner Sombart identified accounting as a formative factor of Western rationality which made the difference (Weber 1980; Sombart 1969; Yamey 2005).[14] Knowledge of accounting was not academic or theoretical, even if algebraic techniques had to be studied as a prerequisite. It was practical knowledge in the sense that it derived from business practices and was trained on-the-job. It scarcely ever found its way back to a theoretical level – unless it was compiled in manuals.[15]

Moreover, the term 'useful knowledge' implies the existence of *useless* knowledge which could be seen as a *contradictio in adjecto*. The 'usefulness' in the context Mokyr argues with could be referred to as 'applied sciences'. The knowledge which is not defined as 'useful' in that sense might be 'speculative' or 'a priori'-knowledge as Immanuel Kants puts it in his *Kritik der reinen Vernunft*.[16]

In the fifteenth century, for instance, practices of accounting were also preconditioned by theological – or at least moral – knowledge in order to adjust economic operations to the Christian model of society. Generally speaking, we cannot be sure of which quality knowledge appeared to be when it came to usefulness (Caferro 2020, 48-51), and in consequence the term «practical knowledge of accounting» is preferred.

Some scholars, following David Hume's observations, have pointed out that any kind of economic knowledge in Renaissance Florence was not theorised, but rather

[11] Marks 2016. With regard to the information revolution Marks' chronology has to be reconsidered and his main argument should be modified: the Second Information Revolution in the economic context was already evolving in the sixteenth century because of the circulating price lists ("Preiscouranten"): Schmidt 2010.

[12] On innovation deriving from technological knowledge: Epstein 2013.

[13] This is even true, if we speak about the measurement of National economic growth: Kaplan and Reinert 2019.

[14] Critique on the concept of 'rationality': Goody 1996, 49-81.

[15] This is much more about the theory of the emergence of 'early modern'" science from the context of practical work as explained by Edgar Zilsel (1976).

[16] Kant 1787, chapter III.

practical. Florentines were well aware of that fact. Economic learning, the same is true for knowledge of accounting in particular, was learning by doing, apart from the elementary skills like writing and reckoning.[17]

In this context a recent study should be carefully reconsidered, because it contributes in a much more *useful* perspective to the discussion about practical knowledge of accounting. Michael Zakim tells us the story about the rise of an entire social class of people. He describes the professional group of the clerks as the engine which made the capitalist's enterprises run. By 'clerks' Zakim understands the white collar workers who became the accountants of the flourishing business enterprises at the daybreak of the Industrial Revolution. In fact, Zakim is talking about thousands of men at white collar working places which expanded in first half of the nineteenth century (Zakim 2018).

What is important here, is the concept of the emergence of a particularly qualified and trained group of bookkeeping staff for accounting. When it came to the very complex personal accounting systems and the diversification of investment in Renaissance Florence at the end of the fifteenth century, a new tiny group of highly qualified bookkeepers – which I call here accountant-experts – emerged. In his article on Iacopo di Tedesco, a Florentine silk weaver, Richard Goldthwaite makes the observation that Iacopo called some accountants in: between 1499 and 1504 it was Francesco d'Albizzo and between 1531 and 1539 Raffaello di Pellegrino Bartoli. These men were paid by a modest sum in order to keep the accounts on the entrepreneur's behalf (Goldthwaite 2005, 78-80). Of course, the number of experts of accounting remained small, and the process should be elaborated by further research on personal and domestic accounting.[18]

2.1 Accounting and accountant

The history of accounting was limited to the evolvement of accounting techniques until the late 1990s. Particularly, the historiography about the development of accounting in the Late Middle Ages and Early Modern Europe is going through a significant change. The practices and cultures of accounting are now considered to understand the economic changes and the varying forms of capitalisation. A special aspect is, of course, the knowledge of accounting.[19]

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[17] Reinert and Fredona 2020, 126-131. In his 'Political Essays' David Hume expands on the Italian blindness to 'thinking' political economy, though they were very good at 'doing' it (127). In reference to Giovanni Botero Sophus Reinert and Robert Fredona argue that, at least in the sixteenth century, Italian thinkers articulated the views on the requested skills for getting wealthy through manufactoring textiles. However, there is no Florentine to be named. In their brilliant article they analyse the Medici account books of the Selfridge Collection showing the business strategies of the Medici wool businesses and production in the sixteenth century.

[18] Goldthwaite 2017 does not tell us the story of the accountant of personal accounts explicitly. However, we find traces of the concept in his resuming article on personal and domestic accounts. The study of the *capitalist rentiers* leads to these hypothesis starting off from Goldthwaite 2020.

[19] Most important in this context was the London initiative for a new accounting history by Peter Miller (1994). For the summary on historiography: Napier 2009. On the changes in historiography and

Accounting should hence be described as processing data. It is a process of organising and abstracting data, which homogenises heterogeneous events or occurrences into a coordination system in order to regularly evaluate transfers economically by pecuniary measurement. Sociologically speaking, accounting is processing data driven by a bookkeeper who employs a cognitive artefact, his account book, to set up a valuating operation. The prerequisite conditions for accounting in this sense are literacy, a linguistic evolvement, and a certain algebraic standard as they were pecuniarily applicable concepts of value. The practical knowledge of accounting, thus, was a set of cultural techniques which the bookkeeper had to dispose of[20].

Only very recently, studies on accounting consider the genuine impact of the bookkeeper's activity. Mechthild Isenmann analyses the accounting in process of the headquarter of the Fugger, when the general bookkeeper, Matthäus Schwarz, proceeded deliberately to resiliencing methods by making use of the account books. The accountant-expert of the Fugger put into practice his own methods of organisation of the accounting system (Isenmann 2019).

Our case study here shows that the ways of applying diversified features of accounting to get along with various problems of refinancing, became quite complex and tricky in the sixteenth century. No matter whether we speak of large business companies like the Fugger or the Welser from Augsburg or the personal accounts of a patrician from either side of the Alpes, at any rate, a good deal of knowledge of accounting was required to cope with challenges, and the bookkeeper was the one who had to set up knowledge of accounting by doing accounting in account books.[21]

3. Training in accounting

Here, we trace back the arrival of the experts of accounting down to the early sixteenth century. Hence, the culture of knowledge of accounting and business economy was evolving long before the academic teaching of business economics (what we may call 'pre-academic knowledge') and, thus, before the professionalisation of the clerk which was still to be born as a social figure. During the nineteenth century the early commercial schools and colleges were founded.

Jacob Soll analyses note-taking as the key competence to systematise knowledge, and comes up with commercial accounting. However, he does not review accounting as a kind of 'useful knowledge' *sui generis*. In fact, Soll refers to manuals of the seventeenth century to describe the instrument of commercial accounting as a technique

new ways of interpretation: Lang 2020. On the perspective of «practices and culture of accounting»: Goldthwaite 2015. On a new understanding of 'capitalism': Levy 2017.

[20] The most significant step forward to a sociological understanding of accounting is by: Lemarchand, McWatters, Pineau-Defois 2014. They borrow the term 'cognitive artefact' from Donald A. Norman (1993). A rather interesting approach is by Llewellyn, Milne 2007: the two authors interpret accounting not so much as a «written, instructional, codified text», but rather as texts which refer to an organisational framing and were to be driven. The sociological concept of accounting as a human-machine-process is described by Lang (2019).

[21] For the Salviati company in Lyon we can reconstruct the methods of dealing with the lease of the duties on silk upon the river Rhône: Lang 2020, 212-13. On the special case of Paulus Behaim from Nuremberg: Isenmann 2015.

which interferes with other methods of note-taking.[22] Manuals, however, do not necessarily represent the practice of accounting, but the theory as for learning.

Hence, in order to profoundly understand accounting of the Florentine sixteenth century, we cannot rely on manuals, instead we have to analyse account books themselves to reveal the bookkeepers' work and their knowledge which formed the processes of accounting of that day. Manuals, as it seems, were used as didactic media, being copied by apprentices, and not so much in commercial practice, as Ugo Tucci puts it (Tucci 1968). In their everyday business, merchant bankers referred to incoming and outgoing letters for the sake of seeking information. As shown by the introductory example, this is even true for the delicate transfer of accounting techniques. For putting transactions into accounts and balancing accounts, the letters written from and to business correspondents preserved the essential data.[23]

The situation in Florence was quite particular: on the one hand the practice and the culture of accounting and accounting techniques were highly refined by then, and the double entry bookkeeping which – in theory – enables the accountant to fully calculate the ongoing business and balance the whole set of accounts, was probably at its best.[24] On the other hand, apparently every young Florentine who became to be a merchant, an artisan or even the patricians in general studied the algebraic techniques at all extent at the abacus schools. After their first years at an elementary school where the pupils learned reading, writing, grammar and some basic Latin language knowledge, they went on to attending the abacus schools at the age of ten or eleven for further three years.[25]

At abacus schools, run by masters of algebra, the arts of reckoning were taught. In Florence, since fourteenth century numerous abacus schools appeared regularly and continuously over the time. Many of the said masters of algebra wrote manuals where they collected and explained arithmetical problems.[26] This particular category of writings like the *Pratica d'arithmetica* of the Florentine Francesco Galigai, which was published in 1521 and many times reprinted, present an enormous number of arithmetical problems as they appear in exchange rates between currencies in gold and silver at different alloy, in the calculation of proportions of prices in relation to different qualities and quantities. In some respect, many of these manuals of algebra give long lists of practical information on currencies and specie. However, these books do not contain any lessons on accounting.[27]

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[22] Soll 2010. Still so: Soll 2014. In the same volume as Soll 2010: Blair 2010. Earlier and more interestingly about the cultural technique of 'note-taking': Cevolini 2006.

[23] On the reluctance of merchant bankers to employ manuals for organising their business transactions and the importance of letters for collecting information: Weissen 2005. For letters as the 'external' component of accounting and the use of letters for organising accounts: Lang 2017.

[24] On the development of accounting in Florence in general: Goldthwaite 2015.

[25] At an early stage of his enormous research on Florentine accounting, Richard Goldthwaite studied the training of young Florentines in the fifteenth century (1972).

[26] Elisabetta Ulivi has profoundly studied that type of schools and the masters of abacus which she identified abundantly (2015).

[27] Galigai 1552, lib. III-V. On the lists of currencies and specie: Travaini 2020. Elisabetta Ulivi confirmed the absence of maunals of accounting in the 'pratiche d'arithmetica' in the Florentiner Late Middle Ages and Renaissance.

If there were any Florentine bookkeeping treatises included in these arithmetic works, they should have been presented like the treatise on bookkeeping published by Luca Pacioli in Venice in 1494 as a part of his *Summa de arithmetica*. Of course, the title does not hint directly to the topic in question. As far as we can see, Pacioli did not make use of Tuscan sources for his considerations on accounting (Sangster 2012; 2016). Probably, there were none.

It is again Matthäus Schwarz, who confirms 'indirectly' the absence of manuals on accounting, before his path breaking compilations. When he started composing his «Musterbuchhaltung», based on the documentation of the Fugger-representative in Venice Georg Spengler, in 1518, Schwarz states a significant lack of teaching material about accounting. Though, at first his «Musterbuchhaltung» served only for his own purposes.[28]

What we do know about Florentine apprentices and young merchants, is that they learned accounting by doing on the job. In the business companies the experienced took the future merchant, the *giovane*, under his guidance in order to show him the proper way of keeping accounts. In 1525 for instance, the elder of the Botti brothers, Matteo, wrote the following advice to his younger brothers, Jacopo and Giovambattista, with regard to the inevitable perfection of accounting techniques:

> […] in this context you do not have to be trained by other persons, what does matter quite a bit, if you are in the need of training, you should have someone who teaches you for a certain period.[29]

In the literature on the matter, there is an ongoing debate about the question whether the refinement and innovation of accounting contributed significantly to entrepreneurial success[30]. Be it or not, the referring knowledge was passed from one generation to another, from the experienced businessman to the apprentice. Accounting knowledge was practical training on-the-job and hence acquainted with by trial and error. This is why we shall imagine the importance of copying letters and accounts for the language of business in general and of accounting in particular, and for the practical procedures (Melis 1950).

The improvement of the learning young merchant can only be asserted by the close study of the account books which are preserved in some cases (Orlandi 2022, 79-82). The method of research on the development of accounting knowledge is a rather fragmented and cumbersome undertaking, because we only are able to climb up from the prosaic and detailed bottom of accounts and letters to the bright top of knowledge.

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[28] Isenmann 2019, 140. The first scholar who quotes from Matthäus Schwarz is, of course, Alfred Weitnauer (1931, 14).

[29] Orlandi 2002, 78 (quotation of the letter there): «[…] in questo non habbia a essere governato d'altri che non importa pocho, quando bene bixogni, tenere uno che l'insegni per qualche tenpo».

[30] Orlandi 2002, 78-9: Michele Cassandro takes a middle ground position and underlines that the evolution and the refinement of accounting techniques did undeniably have some positive effects on entrepreneurial success: Cassandro 1991.

4. The case study: a personal accountant

The following case study exemplifies the production of knowledge of accounting in a proceeding practical process. The *capitalist rentier*[31] Alamanno Salviati, a Florentine patrician grown up in Rome, has left a good deal of evidence, while his main bookkeeper and accountant-expert was the Florentine Matteo Brandolini. We have to dig deeply into the archival material to keep his track.

Alamanno Salviati (1510-1571)[32] never actively operated a business in banking and commerce. However, he held shares in some of the business partnership companies which belonged to his distant cousins and invested huge amounts of money in the loans to the French Crown, for instance, executed by his bankers who did business on the secondary markets of bills of exchange.[33]

Alamanno Salviati also purchased and administered lands which he mainly inherited from his father-in-law, hence from his wife's family. Some of his account books, which were due to the properties of land, were kept by the administrators of his estates. To sum up, Alamanno Salviati's account books fill a whole shelf in the archives at the Scuola Normale Superiore in Pisa, couvering nearly his entire life span as an adult (1530-1571). Some pieces of his series are preserved at the Vatican Library (Rome).[34]

The specific issue about Alamanno's account books is not only the complexity of their organisation, but also their consistency. The ledgers are structured by all accounts necessary for a full double entry bookkeeping as they are entirely balanced. His account books shed light on his style of life – that of a quite well-off member of the Florentine elite – and, above all, on his investments of any kind and the respective return. His expenses are met by the revenues from his land property and from the return of other of his investments. Generally, the profit and loss accounts are used for the regular balance operations in this context. From 1539 on he kept also letter copy books (*copialettere*) and waste books (*ricordanze*). In his letters he explains his transactions, as if he were running a business company on his own. The difference

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[31] The term *capitalist rentier* shall recall two types of capitalists: one the one hand a 'capitalist' who is an active partner of a company and manages his investments for reinvesting. On the other hand the capitalist's investments are meant to produce a return like on real estate or equity like on shares held passively as a 'rentier'. In preparation of my current project at the university of Leipzig «Investments and Practices of Refinance in Crises. Accountability of Commerce and Banking Companies and of Capitalist Rentiers in Florence and Augsburg in the Sixteenth Century» I discussed with Richard Goldthwaite about accounting and the concept of *capitalist rentiers*. I am owing the term to Richard whom I am very grateful for the many jolly dinners we are having for our ongoing debates on accounting.

[32] Some hints at the profile of this particular character we find in the family's biography: Hurtubise 1985, ad indicem (particularly pp. 241-61).

[33] On the context of secondary markets and the loans to the French Crown: Orlandi 2002; Lang 2020 (extending on the issue: chapter V.2). For a broader view to the Florentine merchant bankers and their activities in the French Kingdom: Goldthwaite 2009, 147-64.

[34] SNS, AS, ser. III, no. 17-62. See the recently completed inventory by Cristina Setti: SNS, Centro archivistico, schedario, 11 September 2020. For the Vatican (Biblioteca Apostolica Vaticana): Fiorani 2010 (cf. no. 300-305; unfortunately, this inventory has many errors).

of his correspondences to other surviving material of that time is, that he carefully described his investment strategies.[35]

Matteo Brandolini's, the bookkeeper's, hand appears in Alamanno Salviati's account books from 1 October 1535 on, when he opened the new ledger "B." The *libro debitori e creditori segnato B*, which belonged to the twenty-five years old Alamanno Salviati, seems to be the first professional account book of the series[36]. However, only in late 1539 Brandolini started the whole range of account books with the *copialettere* and the *ricordi* "C"[37]. According to his hand in Alamanno's documents Matteo Brandolini stayed with his master until the 1550ies.[38]

Over the years Matteo Brandolini not only became Alamanno's bookkeeper, but also his minister, administrator in chief and, in some exceptional cases his proxy. In 1540, for instance, Matteo opened an account book due to the return on the shares Alamanno and his brother's heirs, *redi di Lorenzo*, held with their distant cousins' *compagnia* in Pisa:

> This book belongs to Alamanno and to the heirs of Lorenzo di Iacopo Salviati wherein accounts will be kept by me, Matteo Brandolini, and they are about everything what regards the firm of Averardo Salviati & Co in Pisa which is the return of the bank in so far as for the capital stock as for the return divided from today on.[39]

In another ledger we learn that this account book was a *tavola*, a table to keep account of the return on the capital invested in the business company Averardo Salviati & co in Pisa.[40] So, it becomes obvious that Matteo Brandolini was not a "simple" bookkeeper or a scribe, but an accountant with his own expertise.

In some delicate cases Alamanno Salviati sent his accountant and administrator as his representative: in September 1539, Matteo went to Naples in order to collect the amount of money falling due to the liquidation of his master's share which he

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[35] For the state of the art of personal accounts and the implicit difference to business account books: Goldthwaite 2017.

[36] SNS, *AS*, ser. III, no. 21 (Libro debitori e creditori di Alamanno Salviati segnato B).

[37] SNS, *AS*, ser. III, no. 22 (Libro di copialettere e ricordi di Alamanno Salviati C).

[38] SNS, *AS*, ser. III, no. 25 (Libro debitori e creditori di Alamanno Salviati C).

[39] SNS, *AS*, ser. III, no. 24 (Alamanno e redi di Lorenzo di Iacopo Salviati per la ragione di Pisa, 1540-42), frontspitz: "Questo libro è di Alamanno e redi di Lorenzo di Iacopo Salviati sul quale si terrà conto per me Mateo Brandolini di tutto quello e loro tochò della ragione di Pisa di Averardo Salviati e co per l'adreto dell bancho tanto per il chorpo quanto per li utili divixa questo dì."

[40] SNS, *AS*, ser. III, no. 21 (Libro debitori e creditori di Alamanno Salviati segnato B), ac 177: «[…] che tanti se ne fa creditore Averardo Salviati e co della Maghona di Pisa per l'adreto che tantj mi tocha a paghare per la ª/2 di ß 8.7 ⁰/2 per lb participavo in detta Maghona di duc 2213,11,1 di moneta di creditorj erano in detta Maghona in dì primo di novembre proximo paxato che me ne tocha fl 477.5.6 di moneta dj ß 8.7 ⁰/2 per lb cioè la ª/2 e per avere sopra preso Averardo e Piero Salviati propri duc 267.18.7 e Stagio Barduccj e debitori di duc 292.2.10 che ànno per mia apparte quello ànno sopra preso e quello restano debitori di modo che mi tocha dettj duc 337.5.8 di moneta per mia parte come di dice al Gior ac 146 e per jª tavola che sono de scripti dettj creditorj al Giornale ac 171 e li si dice partiqularmente j° dettj dj Maghona avere a bonconto per quando li aranno paghati a detti creditori e non altrimenti».

had inherited from his father. Jacopo Salviati, Alamanno's father, was a shareholder of Averardo Salviati & co in Naples during the years before his death. By then, we are talking about a remarkable amount of money, Matteo had to receive 1,050 *ducati di carlini* on Alamanno's behalf, which he explains in Alamanno's Journal in detail[41].

On other occasions, Matteo Brandolini became even Alamanno Salviati's attorney. On 21 May 1548, he wrote down an entry in the recently opened ledger "C" of his master, that he was to represent claims and obligations after Alamanno's death:

> + Nota that today, May 21st, in 1548, Messer Alamanno Salviati commissioned me, Matteo Brandolini, that I should write this nota: the said *Capitano* Francesco de' Bardi is debtor [of *fiorini* 47.1.6]. [Messer Alamanno] deliberates that *Capitano* Francesco could not be asked for repayment, if he could not make it during his life time to repay or even if he could dispose of the sum in another way, and [Messer Alamanno] does not want that the heirs [of *Capitano* Francesco] could be forced to repay. And [Messer Alamanno] will release [*Capitano* Francesco] from paying back in case of his death; in the case of his death no one should be allowed to make the claim. [Messer Alamanno] only insists on his right of asking [*Capitano* Francesco] and making him dispose of the due sum in another way than this nota says. If [*Capitano* Francesco's] heirs do not have any means for repayment, they should not be claimed to do so. In the very case a favourable nota should be added ex post to his testament.[42]

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[41] Biblioteca Apostolica Vaticana, *Archivio Salviati* (further on: BAV, *AS*), no. 305 (Libro Giornale di Alamanno Salviati segnato B), ac. 168r: «+ addì 13 di setembre 1539 // Richordo questo dì detto chome Mateo Brandolini mio proqurato à venduto a Bernardo di Ridolfo da Sommaia tutta la parte mia chosì de lj utili debitori e entrate che avevo per l(etter)a della redita di Iac(op)o mio padre nella ragone di Napoli che chantò in Averardo Salviatj e co di Napoli e chominciò l'anno 1517 e finì l'anno 1530 in circha et s'è acholato tutto il bene e male di detta comp(agni)a e per ogni mio resto della a/2 del 0/3 participava detto Iac(op)o mio padre m'à a dare duc millecinquanta d'oro di k(arli)ni di Napoli ap(ar)e ogni anno la metà e di più mi lasc[i]a la a/2 di duc 510.1.5 e' debitori Filippo da Sommaia e la a/2 di duc 554.1.16 e' debitori Ghuglielmo da Sommaia per conto de' tempi e di più la a/2 di duc 513.2.8 e' debitore Ghugl(iel)mo Nasi e co di Firenze che questo s'intende la a/2 del 0/3 che participava mio padre in deta ragione el altra metà resta allj eredj di M(esser) L(orenz)o mio f(ratel)lo e di più mi da la a/2 del 0/3 di duc 513.2.8 e debitore Ghugl(iel)mo Nasi e co di Firenze che aspetava al detto Bernardo per la a/2 della parte sua di detto debito e di più mi sono reservato le ragone contro a Averardo e Piero Salviati per conto delle partita dj Bernardo Braccj e co di Roma di duc 543.4.9 e ognj altra chosa resta al detto Bernardo da Sommaia e mi à promesso chavare d'ogni danno che per tenpo alquno potessi avere per detta comp(agni)a come di tutto apare contrato roghato Ser [lacuna] j'Napoli sotto dì tredicj di setenbre e questo dì 4 d'otobre detto Alamanno retifichò al detto contratto / Nota che'l detto Bernardo à promesso paghare dettj duc 1050.- dj k(arli)ni a me a Mateo Brandolini con M(esser) Rafaello da Sommaia liberamente e senza alquna ecezione».

[42] SNS, *AS*, ser. III, no. 25 (Libro debitori e creditori di Alamanno Salviati C), ac. 28: «Nota che questo dì 21 di maggio 1548 M. Alamanno Salviati à chomesso a me Mateo Brandolinj che jo faccia questa nota chome di quello è debitore il sopradetto Capitano Francesco de' Bardi non vole gli possino essere domandatj, se non da luj e non li avendo rischossi o dispostone in contrario in vita sua, non vole [che] possa essere stretto a pagharlj dalle sua rede e gle ne dona in chaso chome è detto, ch'alla morte di detto M(esser) Alamanno non avessi paghato ho altrimenti dispostone in contrario e non vole persona lo possa risquotere e lui si riserba solamente il poterlj domandare e disporre secondo li parra in contrario chome si questa nota fatta, non fussi e non avendo reschossi o dispostone le sua rede non gle ne possino domandare che disse esserselo sdimentichato di meterlo sul testamento».

Sometimes Matteo Brandolini represented his master in far less significant contexts than the liquidation of shares in business partnerships, when he had to carry some cash to the coffers of Alamanno. On 4 December 1543, he puts down 50 *scudi di sole* which were to be paid by Maria de' Salviati, mother of Duke Cosimo:

> I remember that today I, Matteo Brandolini, received *scudi* 50 *di sole* from *Monna* Maria de' Salviati paid by Tommaso de' Medici which are paid on the account of Don Giovanni di Lunagia, *castellano*, out of a share of *scudi* 150 *di sole* which Alamanno borrowed him some time ago […][43]

Since we recognise Matteo's hand, we know that it was him receiving the amount by cash, which was only the third part of an entire loan of 150 *scudi di sole*, and, then, writing down the incoming transaction on his master's behalf.

In 1537 Alamanno Salviati married Costanza Serristori (c. 1522-1538) who was the only child of the very wealthy merchant banker Giovanni Serristori[44]. Giovanni had prematurely died in September 1531. At the time immediately after his death, two series of account books were opened upon his legacy, both called 'heirs of Giovanni Serristori'. One took account of the shares Giovanni held in the Serristori *compagnia*, the other referred to his personal properties. The marriage between Costanza and Alamanno was arranged one year later in 1532 by the mother and widow, Camilla, and the executors of the last will respectively, on the one side, by Alamanno Salviati on his own on the other side[45]. These said two series of account books passed from the bookkeepers of either series to Matteo Brandolini's hands, as Alamanno became the administrator of Giovanni's properties alongside the dowry, the *dota*[46].

Matteo Brandolini's impact on Alamanno Salviati's accountancy was not at all insignificant. When he opened the above-mentioned ledger «segnato B», he elaborated his master's system of accounts and developed a technique of full double entry bookkeeping. Later, just before the start of the following ledger «segnato C», he began to copy the outgoing letters and put down «ricordi». On 13 November 1539, Matteo registered a letter to Averardo e Piero Salviati & co in Lyon which spells out like the following:

> Dear friends etc. in my last letter I wrote that little which happened. The present letter shall only tell you that Francesco Bandini & co is drawing *marchi* 40 [*d'oro*] on you in some rates from Florence on my account due on the fair of All Saints. [I am asking you to] promise payment and to pay. At the time being

43 BAV, *AS*, no. 300 (Libro Giornale di Alamanno Salviati segnato C), ac. 335v: «Ricordo questo dj detto come jo Mateo Brandolini ho riceuto da Monna Maria de Salviati e per sua S(igno)ra da Tomaso de' Medicj ∇ cinquanta di sole e' qualj pagha per conto di Don Giovannj di Lunagia chastellano per parte di ∇ 150 li prestò Alamanno più fa […]».

44 On the Serristori family: Tognetti 2002 (Unfortunately, this wonderful book does not talk about Giovanni Serristori and his daughter).

45 SNS, AS, Filza 58, no. 6. Apparently, behind this arrangement was the Duke of Florence, Alessandro de' Medici: Hurtubise 1985, 248.

46 BAV, *AS*, no. 380-392 (Libri delle redi di Giovanni Serristori).

> put it on my account which is the amount of *scudi* 2,600 *di marchi* and you ought to pay *scudi* 12,012.7.6 *di marchi* to Tommaso Guadagni & co due on the said fair. [Tommaso Guadgani & co] disposes of an order by a letter which they will present you. In total you should put me *proprio* on the debit side at the amount of *scudi* 14,612.7.6 *d'oro di marchi*, and we should proceed as said before in another letter from your Lorenzo [Pasquali] of 11 August 1539. If any error occurs in your or our accounts, I ask you to balance [my account] by the amount requested, and hence we should always turn back to my indebtedness and the following balance payment. The present letter serves as a receipt for this account.[47]

For the dimension of the values exchanged we may underline that Alamanno Salviati was dealing with enormous amounts here. It is an investment with the company of his distant cousins' banking business in Lyon which comes close to the total of the capital stock which was in the very Salviati-company due to the contract of 1532 (*scudi di marchi* 12,000).[48] This reflects a tendency which evolved in these years: investors from outside gave growing financial means to the internationally operating banks in order to profit from the returns (Lang 2020, 503-25)

The cited lines do not show any difference to letters between business companies, reporting prescripts of transactions to set up commercial or financial transfers and, then, to balance the accounts. At the beginning we have already noticed how business letters prescribed practical aspects of accounting techniques. But they also were the channel of communication between two business companies where accounting and economic techniques appear as a process of practical knowledge. In other words, the merchant bankers and their bookkeepers learned and refined their accounting techniques by doing (Goldthwaite 2011).

'Doing', hence, means that they explained in their letters what they were *going to do*. Up to a certain extent they had to know what to do and how to execute it. However, in the letters to their fellow merchant bankers they extensively described the transactions they aimed at. An essential issue was the balance of the open accounts which the business transfers were to put on (Lang 2020, chapter VI).

Thus, by writing letters the merchant bankers created «communities of practices». Knowledge in that context was continuously referred to in pragmatic terms and thus implicitly. Of course, this is to be repeated, merchant bankers and their bookkeepers

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[47] SNS, *AS*, ser. III, no. 22, c. 1v: «Amici car(issi)[mi] etc. al pax(a)[to] ve s'è scripto quel pocho n'è hochorso. la prexente solo per dirvj che da Francesco Bandinj e co di qui vi è stato trato per mio conto jn questa fiera proxima di Tutti Santi in più parte m(archi) 40.- d'oro prometetelj e paghatelj, al tempo conporlj a mio conto che sono ∇ 2600.- di marchi e ∇ 12012.7.6 di marchi pagherete in sudetta fiera a Tommaso Ghuadagni e co ànno hordine come per j[a] [lettera] d'avixo da loro vi sarà presentata che jn t(utt)[o] sono ∇ 14612.7.6 d'oro di marchi che mi fece debitori e li tenevj da me p(ro)p(r)[io] con le condizione che eramo d'achordo e chome apare per j[a] lettera del vostro Lorenzo fatta qui sotto dì xj° d'aghosto paxato e quando nel conto vi fusse erore per voj ho per noj paghate le somme dete e senpre si farà tornare a dovere e paghato avere le sudete forme la prexente vi serve per quitanza per questo conto/».

[48] Lang 2020, 197. The following contract in December 1539 established a stock capital of *scudi di marchi* 20,400 with a share of Averardo e Piero Salviati di Firenze at *scudi* 15,000 *di marchi*.

had to know what to do and how to do it, but the single transaction was anticipated by explanation.[49]

Matteo Brandolini behaved in the same way. Since he probably had experienced a merchant's education attending the elementary school and, thereafter, classes of an abacus master. With this education as knowledge base he entered service in a business company. When he arrived at Alamanno Salviati's household – at his office – he was ready prepared. He obviously did not copy letters to learn the businessman's idiomatic language and he had not to learn how to understand account books anymore. He apparently was a well-trained expert at accounting (Goldthwaite 2015).

In 1543 Matteo Brandolini put down a whole balance sheet with his own comments in the waste book 'A' of the heirs of Giovanni Serristori, which had passed on to Alamanno Salviati after his wedding to Giovanni's daughter Gostanza. Therein, he draws the sums from account books of the Serristori-series and wrote off debts that would never be paid back. Furthermore, he explains from one account book to the next the reasons for these markdowns. It is evident that Matteo Brandolini was taking notes of his procedures in order to justify how he kept account of what he was doing.[50]

This practice of accounting could be confirmed by comparing with the accounting techniques developed by the bookkeepers in chief of the Fugger: Matthäus Schwarz and, a generation later on, Melchior Geisstetter transformed the accounting system of Anton Fugger into a much more complex device. The most significant difference to what Matteo Brandolini did is, that Schwarz and Griesstetter wrote manuals on accounting to hand over their practical knowledge to the next generation of bookkeepers. Brandolini did not make that effort (Isenmann 2019, 141-53).

5. The new type of the accountant-expert

In the early sixteenth century accountant-experts like Matteo Brandolini appeared in the service of wealthy Florentine households when the patricians started to diversify their investments. Particularly, the combination of various forms of assets which had to be treated created the demand for this tiny group of experts. Of course, most of these merchant banker-patricians were still active partners in their business partnership companies, but some of them already tended to only hold shares in the companies of their relatives. In this case they were silent partners who kept account

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49 This point I have made earlier: Lang 2017. On the concept of «communities of practices»: Wenger 1998.

50 BAV, *AS*, no. 394 (Giornale e ricordanze dell'erede di Giovanni di Battista Serristori, Rosso segnato A), ac. 146r-149v: «Ricordo questo dì detto come se aconciò a' Libro Rosso segnato A a 194 della reditá il conto di Giovanni Serristori e co linaiuoli in San Martino e se aconciò li utilj come a deto libro si dice e si sono tiratj di poj a Libro segnato E Giallo a 16 dove erano debitorj per conto del chorpo e non s'è saldo detto conto e chancellato perché non si trova maj che queste partite dappiè ne sieno itj debitori a libro del nostro magiore Giovanj de chosì anche sono itj creditorj delle apresso partite e per non sapere chome abbia da stare si sono notate qui dappiè donde venghano e a che libri appaiono perché el deto Libro E restano creditorj di duc 33 in circha e non ànno a essere e di più chome è detto non si trova dieno aconce le apresso partite in loro debito e credito e prima».

books to pursue expected returns on their capital invested. For their personal accounts, however, they engaged experts like Matteo Brandolini.

The wealthy patricians from cities like Florence, Genoa, Augsburg, or Nuremberg were the main investors in the loans provided to European Crowns. Their capital was transmitted through expanding markets for letters of exchange: the latter were secondary markets, set up to refinance the investments of capital (Lang 2020, chapter V.2). Especially in this context, the patrician investors did not deal with their accounting themselves, instead they employed personal accountant-experts who not only kept their books, but also represented their masters in various context as proxies or acted as their agents. In that sense, the personal accountant and agent, like a minister, had to coordinate the various fields of activities of their masters. The bookkeeper became an accountant-expert who had to figure out the chains of investment.[51] What we do not know, of course, is how strictly masters like Alamanno Salviati supervised their accountants. It is rather difficult to judge the impact of the practical knowledge of the patrons. The accountant-expert like the bookkeeper surely did not act autonomously in business affairs as if he were the head of the household. Nevertheless, he was not dependent on his master's advice how to keep accounts. The accountants of the new type became at least the right hands of their masters.

In the fifteenth century the role of the personal bookkeeper, the household's accountant, was at a lower profile. Of course, there were private secretaries like the famous Ser Alessio Pelli who was the minister of Cosimo de' Medici's household as described by Dale Kent in her study on «the patron's oeuvre» (Kent 2000; Lang 2009). It was particularly the diversification of investments that made the difference: when the merchant banker's families became rich by the changing distribution of wealth in their favour within society, they started to diversify their investments (Goldthwaite 1995). At the end of the fifteenth century about 70 percent of the whole family properties were invested in businesses and about 30 percent in land. The situation one hundred years later was inverted, and the properties had grown in total[52].

However, historiography has not discussed in detail the investment of the wealthy merchant banker's families in the secondary markets during the sixteenth century, yet. In the context of further research, other personal accounts like the ones of Andrea degli Strozzi or Giovanni Quaratesi and Battisata Manzuolo may reveal the same appearance of accountant-experts (Goldthwaite 2017).[53]

The new type of accountant-experts was called in to handle refinancing in terms of accounting. Thus, the bookkeeper left his prior role of a scribe behind and took gradually more responsibility for the administration of his master's properties. This change in the function from a personal secretary to a personal expert of accounting was a symptom of the evolution within the structures of wealth. Maybe, this new

[51] For the concept of 'expert' and further literature: Rexroth 2012.

[52] The first study to draw the lines of that tendency: Malanima 1977. On the Salviati in particular: Pinchera 1999.

[53] Archivio di Stato di Firenze (ASFi), *Strozzi Sacchetti*, ser. I, 516; 517; 521; 524; 525; 582 (Andrea degli Strozzi). ASFi, *Compagnie religiose soppresse*, 1027, 211 (Battista Manzuolo). ASFi, *Quaratesi*, 87 (Giovanni Quaratesi).

type of accountant-expert even promoted the ongoing diversification of investment. For sure, this new type of accountant was not a simple clerk, but an expert in bookkeeping – and economic affairs. The same might be true for the process of accounting driven by accountant-experts on the behalf of business partnerships in the context of emerging markets and new opportunities around 1500 (Goldthwaite 2020, 316-35). However, the story of the 'logic of capitalism' and accounting may be a history we have to re-write.

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Tanja Skambraks

Tally sticks as media of knowledge in the contexts of medieval economic and administrative history

Introduction

This paper will present and discuss tally sticks as ubiquitously used objects that played a vital role in medieval and early modern book-keeping, in the administration of goods in trade and agriculture as well as for the public financial sector of some medieval societies. These objects have a very long history as means of quantification, counting and accounting. They were stores of operational knowledge necessary in all spheres of economic life. Furthermore, their long-lasting role as proofs in court highlights their perception as wooden charters – a function that can be traced up to the Code Civil from beginning of the nineteenth century. Tally sticks are modest-looking objects: wooden sticks of varying length carved in different ways and manners. As mentioned, they were used in a wide field of contexts, from agriculture, demesne production and consumption, to the Hanse trade and the tax collection of the English Royal Exchequer.

The first part of this article will discuss some of the specific formal features and the production of those objects. The second part will deal with the functions of tallies in several contexts, linking them to the general themes of this conference asking: how was essential numerical knowledge stored, inscribed and administered? And how did tally sticks work as basic instruments of counting, as wooden charters, as receipts of taxes collected by English sheriffs and as an alternative currency in England? Thirdly, the paper will analyze the relationship between written sources and the objects asking in what ways these two means of documentation and storage of knowledge corresponded and interacted.

Obviously, the topic of knowledge and economic productivity will *not* be approached from the perspective of a history of ideas and concepts, but rather from the perspective of material culture and the practices linked to it. Thus, the paper will contribute to the more general question, how innovations and/or respectively long-term techniques of documentation fostered effectiveness in administration and economic productivity.

Themes and subjects of tally research

The Finnish historian Axel Grandell (Grandell 1982, 1988) described tally sticks in the 1980ies as «forgotten media of culture», pointing to the fact that they are also among the forgotten topics of medieval studies. One reason for this neglect might

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Referee List (DOI 10.36253/fup_referee_list)
FUP Best Practice in Scholarly Publishing (DOI 10.36253/fup_best_practice)

Tanja Skambraks, *Tally sticks as media of knowledge in the contexts of medieval economic and administrative histor*, © Author(s), CC BY 4.0, DOI 10.36253/979-12-215-0092-9.09, in Giampiero Nigro (edited by), *L'economia della conoscenza: innovazione, produttività e crescita economica nei secoli XIII-XVIII / The knowledge economy: innovation, productivity and economic growth,13th to 18th century*, pp. 137-158, 2023, published by Firenze University Press, ISBN 979-12-215-0092-9, DOI 10.36253/979-12-215-0092-9

be their dispersed and rather confused state of tradition. The second reason might be their rather 'dusty' and perhaps even dull image, since they hitherto appeared mainly in older works on folklore, administration and legal history. However, the wooden sticks deserve a central place in a longue durée history of book-keeping, administration and accounting, but also in the history of knowledge. Bernard Berthet (Berthet 1949) first raised this topic in his enquête (supervised by Marc Bloch and) published in the Annales in 1949 and Jean-Jacques Hémardinquer (Hémardinquer 1963) addressed the use of tallies as an essential human 'technique intellectuelles'. Notching stones or wood is a universal human cultural technique of information storage, ranging from the clay marks and cuneiform clay tablets of Mesopotamia, to the ostraca of the Egyptians, into the modern period. Numerous pieces of evidence have also been preserved from medieval times, showing the widespread use of the sticks for manifold purposes, like calculating quantities of goods, services, duties and rights, and later money.

More recently, tally sticks and their widespread use in most of Europe were contextualized by Michael Clanchy in his book *From memory to written record* (Clanchy 1979), Axel Grandell (Grandell 1982; 1988) as well as by Ludolf Kuchenbuch (Kuchenbuch 1999; 2002) and Moritz Wedell (Wedell 2011). All of these authors emphasized the potential of these objects not only for the social and economic history of the middle ages, but also for the history of writing and numerical knowledge from an anthropological perspective. Whereas Clanchy described tally sticks as objects marking one of various stages of information storage on the way from non-written society to writing, I would instead follow Wedell and like to propose an interpretation of the tally sticks as para-literary media accompanying and complementing written documents. If one compares, for example, the form of tallies, tally bills and the entries in the English Pipe Rolls, we can see the successful adoption of a reduced, formalized and abstracted way of documenting administrative data that seems to be directly linked to the pragmatic use of writing space and essential knowledge about the King's income.

Hence, the application of tally sticks very often paralleled the usage of written documents. The ongoing use of both materials clearly shows that the increased employment of parchment and paper in the middle ages did not lead to the disappearance of older forms of documentation. This duality of written and nonwritten information storage is a fascinating feature of the history of medieval book-keeping and administration and provokes further questions about the role of literacy in processes we would call 'cultural development'. The English anthropologist Jack Goody challenged the supposedly essential role of the written word in his book *The domestication of the savage mind* (Goody 1977), suggesting that in non-literate cultures oral complexity was often reduced to graphic simplicity. In doing so, he ultimately questions the presumed causality between writing, abstraction and cognition as the only means of knowledge creation. Especially in administrative contexts, the use of reduced sign language seems to have been functionally sufficient. Along this line of research, i.e. in a trans-cultural and trans-epochal perspective, tally sticks can be interpreted alongside any form of sign language or material objects that contain numerical and even narrative information, such as the Inca *kiphus* (Urton 2003;

Hyland 2017, 2019) or tally finds from Bactra from the Achaemenid Empire (Henkelman and Folmer 2016).

Hence, the history of accounting did not begin in Europe, and certainly not with individuals like Luca Pacioli. Instead, work from the prehistory of the Middle East and Africa (Sy and Tinker 2006) provides ample evidence for the existence of techniques and media of (ac)counting long before European history 'began'.

Beside anthropology, historical semantics has also dealt with writing and cognition. Commenting on their value as sources for the history of communication and ritual, Wedell writes that Tallies «do not function in a purely message (i.e. semiotic) way, but inherit ritual (i.e. performative) properties» (Wedell 2011, 258). Interestingly, he emphasizes not only their role as a para-literary media, but also their associated agency in the context of the accounting process as a ritual. Thus, tally sticks can become research objects in an administrative and legal history framed by the approach of ritual studies and material culture.

Finally, the history of calculation and numbers (Menninger 1992 (1969); Ifrah 1981) conceived of the number signs on the sticks as primitive numerals and thus as part of a general culture for ordering and grouping, especially in rural communities. They served above all to store partial and final results and thus enabled the complete traceability of a particular calculation. The transparency of calculations was the basis for streamlining administrative practices, including the quantification and categorization of entities. In a kind of logical continuation, institutional economics has also dealt with the role of tally sticks. In one study of common property management in 17th century Sweden, Per Forsberg (Forsberg 2018) has interpreted tallies as technical media facilitating the management of the commons and consequently the ability of rural societies for self-governance. He shows, that as debt records and documents of individual as well as common obligations and rights, tally sticks became mediators for social relations, decision-making and transparency in Swedish village communities. Counting and accounting techniques are seen here as a fundamental skill of economic actors that enforce mutual cooperation and ultimately stabilize social relations. Considering all these approaches, the role of the modest tally sticks for the grand narratives of economic history becomes obvious.

1. Forms and types of tallies

By way of definition, tallies were wooden sticks of varying lengths that used cuts and notches to document numerical information in different contexts, such as debts, taxes, traded goods and agricultural services and production. Beside notches, we sometimes see inscriptions providing additional information on dates, places and actors as well as reasons for the payments. Tally sticks appear in a considerable variety of forms and functions, as these illustrations demonstrate.

Fig. 1. **Various types of tallies (depicted in Grandell 1988, 50, 95, 127, 144) and one Exchequer Tally (from 1294, NA, E 402/1 (photo by the author))**

The formal and functional diversity of tallies is striking, ranging from Swiss lot pieces (Gmür 1991 (1917)), simple and bipartite sticks used for cargo in Bryggen/Bergen and Novgorod (Kovalev 2000; 2007), both important centres of the Hanse trade, to the elaborate Exchequer tallies (Jenkinson 1911; 1924). Even tripartite tallies (for instance in the so called fork-form) exist, showing the involvement of three parties in one transaction (Grandell 1982: 95; Menninger 1992 (1969), 231).

Beside their haptic qualities as tangible proofs of legal and power relations, tallies were most useful, because they could be used by illiterate people as well. Furthermore, they were much cheaper than parchment or paper. The main advantage of tallies was their safety against fraud, because each bipartite tally was a unique piece of wood split after notching into two parts, the stock and the foil. The stock was kept by the payee, the foil by the payer. Therefore, they can be interpreted as a sort of wooden charter, proving the authenticity of a transaction. Unsigned, they were – in some contexts – transferable from one person to another. In the case of medieval England, they even developed into a form of promissory note, cheque and money substitute, as will be shown later.

1.1 English Exchequer and private tallies

Not only do we know tally sticks from England that point to an elaborate centralized administrative practice of the crown in the high middle ages, we can also trace their long history until the early 19th century. The example of England illustrates the functionality of these instruments on many levels particularly well. Their use is best documented for the English treasury, the Exchequer, certainly since the 12th century, very probably earlier. In England, tallies were still used as tax receipts until the 19th century, although a system of documentation fully based on writing had long been practiced. It was not until 1826 that the English government decided to abolish these accounting instruments, which then were considered obsolete. This quotation from Charles Dickens vividly illustrates the 19th century attitude to pre-modernity:

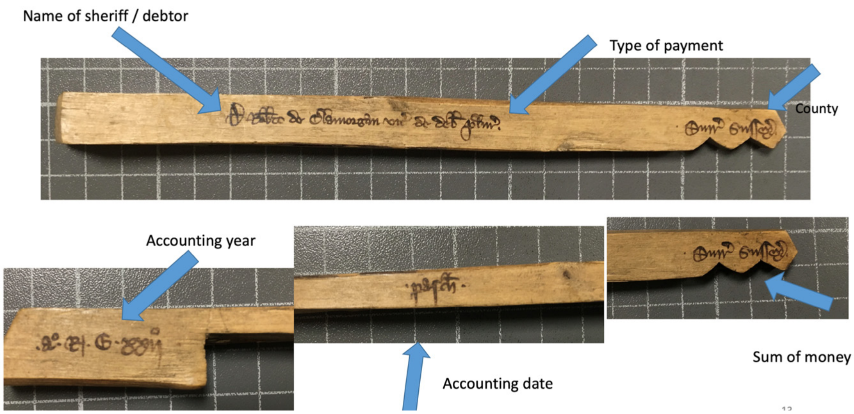
> What was to be done with such worn-out, worm-eaten rotten bits of wood, which ages ago a savage mode of keeping accounts had introduced into the Exchequer? (Dickens, Speeches, ed. Fielding 1960, 204f.).

The course of this fatal decision is well known: The burning of millions of dry tallies famously set on fire the Houses of Parliament, as depicted by William Turner.

So, what is left then for historians? In 1910 a box was found in the in 'Chapel of the Pyx' in Westminster Abbey, containing a number of tallies from the thirteenth and fourteenth century AD. These finds were first described by the English archivist Hilary Jenkinson at the beginning of the 20th century, who distinguished two main types (Jenkinson 1911): the Exchequer tallies and so called 'private tallies', which closely resembled those of the Exchequer in their form. On the basis of these remains, which consist of ca. 400 pieces, as well as the parallel written tradition, the following contexts of function and use can be deduced.

The Exchequer tallies came into being in the course of the annual settlements and accounting of the royal tax revenues. The sheriffs' accounting procedure took place twice a year at Easter and Michaelmas at the Exchequer in Westminster. As tax collectors, the sheriffs were held personally responsible for the payment of several taxes and duties, for which they were issued tally sticks as receipts for payments made or still outstanding.

Fig. 2. **Exchequer tally from 1294, NA,** E **402/1 (photo by the author)**



They contain a range of information, such as the names of the respective official and the county, the year of accounting, the accounting date as well as the type of deposit and, of course, the amount of money paid in form of notches in the wood.

The most striking feature is that these notches are cut in a specific way, already described in 1170 by the King's treasurer Richard of Ely in his famous treatise on the work of the Exchequer, the *Dialogus scaccarium*. There we read about the precise assignment of certain values and notches:

> The method of cutting is as follows. A thousand pounds are shown by a cut at the top of the tally wide enough to hold the thickness of the palm of the hand, a hundred that of the thumb, twenty pounds that of the little finger, a pound that of a swelling barleycorn, a shilling smaller, but enough for the two cuts to make a small notch. A penny is indicated by a single cut without removing any of the wood (Richard of Ely, Dialogus, ed. Johnson et al. 1983: 23).

The accounting process could take several days and was highly ritualized. The accounting took the form of a court case or a game of chess, as Richard of Ely described it. The sheriff sat on one side of the table and the treasurer as his 'opponent' on the other side. The sheriff had to defend himself by supplying the necessary tax sums for which he was personally liable. He remained the king's debtor as long as sums had to be paid in. After he had deposited the money (in coins) with the lower treasury, it was weighed, tested for its metal content and stored in canvas or leather bags.

Fig. 3. **Convolute of tallies, related written documents and canvas bag (Jenkinson 1924: plate LXV)**

PRIVATE TALLIES, STOCKS AND FOILS

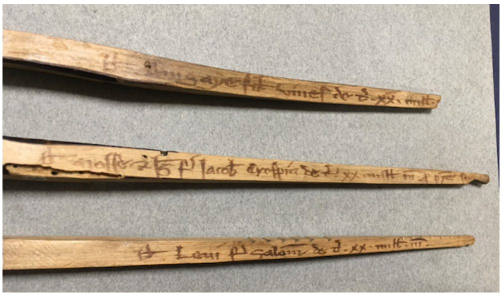
with canvas bag, descriptive label, and rolls of accounts: 14th cent.

about ⅓

Then a tally stick was carved and taken to the upper treasury. There, after the hearing, the sheriff received the tally as a receipt. Simultaneously, the incoming amounts were written in the receipt rolls, the famous Pipe Rolls. These books also recorded the sums of money that were still missing. Tally sticks were thus used alongside written documents. Their tactile quality and their character as take-away receipts and evidence of the accounting 'trial' made them indispensable items alongside the rolls. A ritual character can be attributed to the accounting procedure itself, which increased the value of those sticks not only as an instrument for quantifying and storing information, but – beyond that – as a symbol of a social relationship and personal commitment, produced by a financial transaction. Tally sticks were also issued as promissory notes instead of cash, for example for goods purchased for the king's wardrobe.

The English National Archives also hold a series of Jewish tallies, which document the payments of *tallage* and taxes on chattels of the Jewish communities under Richard II. Interesting features are the Hebrew script and the varying quality of the wooden sticks depending on the amounts paid. It is noteworthy, for example, that sturdier, thicker woods were used for higher amounts over 25 pounds, while thin woods were notched for lower amounts.

Fig. 4. **Three Jewish tallies (thirteenth century), NA, E402/2 (photo by the author)**



As mentioned earlier, the use of tallies was not limited to royal administration, but was also a widespread practice in business between private persons. Looking at transcriptions of writings on private tallies, we see that they were used for different purposes by nobles, communities and citizens alike. The private use of tallies is far more varied, as the types of payments mentioned on the sticks prove. Thus, they appear for transactions of credits and goods, between individuals, villages and guilds, to the trading horses and solving family-related problems.

Examples:
1. *Whathamsted. Tallia Roberti Bernereve ibidem de frumento tam dominici quam decimarum ab eo recepto post festum Michaelis anno vij.* (1278)

2. *Contra Philippum Harneys et Thomam Aylred de denariis sibi liberatis de*

sexta domino Regi in villa...(lower edge: *ad construccionem galie eiusdem domini Regis ibidem*) (1294)

3.*Contra Johannem de Leycestria de Ebor' pro xiiij. sextariis vini* (1305)

4. *Contra Hugonem de Litton et socios suos de Mina ab eis recepta ix. die Marcii ano decimo* (on lower edge: *x. lad' disc albe*) (1316)

Furthermore, these objects are evidence for the transregional adaptation of an obviously effective technique of bookkeeping all over England. One interesting question yet to be solved is if the local administrators, the sheriffs, and other royal officers were the only original promoters of tally use or if other groups, like merchants, traders, craftsmen or peasants also played a role in spreading and implementing this practice.

2. Contexts of use

2.1 Manorial administration and husbandry

Although we are well informed about the use of tallies at the English royal court by the surviving objects as well as the Dialogus, rather little is known about other contexts of tally use. Therefore, the analysis of their use as mentioned in contemporary written sources is instructive. Here, extracts from three contemporary didactic treatises on husbandry and household administration will be presented, all of them stemming from the thirteenth century. These texts were very likely written by and for professional administrators working for noble households. They deal with the administration of landed property and livestock as well as what we would call today 'good leadership' from a very pragmatic and realistic perspective (see Oschinsky 1971, passim). The first example comes from the anonymous Husbandry (*Hosbondrie*) about the office of the bailiff (reeve). The Hosbondrie's passage concerning the office of the reeve, who was responsible for the land and its yield, reads as follows:

> And the reeve ought not to sell or buy, receive or deliver anything unless by tally and good witness (Hosbondrie, ed. Oschinsky 1971, 441).

Here, in contexts of trade, buying and selling, tallies were used as receipts. Another passage from the same text describes the procedure of administering the quantities of threshed grain after the harvest:

> [...] And if there are stacks outside the grange then he ought to have them measured by foot or by rod – the width and the length and the height–when he is about to thresh. And he ought to tally every stack by itself, in that way he will be able to assess the yield of the corn equally well for every stack inside as well as outside the grange. […] And although he may sell his corn in

> gross it is advisable that he has one of his own men tally and check the contents of each stack inside and out […] (Hosbondrie, ed. Oschinsky 1971, 421)

Here the tallies mark the quantities of haystacks as part of the threshing process. Although we actually do not know much about the degree of literacy of the reeves and servants using them, it is clear that their use did not necessarily require knowledge of reading and writing. On the other hand, the tallies could be interpreted as evidence for the existence and work of a little-known group of medieval *laici literati*, including a number of literate and legally trained professionals – we could call the administrative elite of the realm – without any clerical background. (Oschinsky 1971, 62)

Similar to manorial administration as described in the 'Hosbondrie', tallies were used for the documentation of correct measurements of grain and hay as described in the treatise called 'Senechaucy':

> c.39: No heaped measures ought to be taken from the grange into the garner to account for the 'increment' but with every eighth quarters – in levelled measures – a ninth should be taken from the stackers for 'increment' (that is to equate the standard measure used at the garner with the larger local one used at the grange). No bushel, half bushel, or cantle should be handed over to the reeve from the threshers over and above the foresaid measure. The heaped measures and the bushels, half bushels, and cantles and any odd amounts which enter the garner without tally or number bring the lord little profit. (Senechaucy, ed. Oschinsky 1971, 277)

> c.40: Seed-corn left over in the fields after sowing and returned to the garner ought not to be measured or tallied a second time; and the bailiff ought to take care that the lord suffers no loss through the reeve or anybody else on account of returned seed or the use of heaped measures, or any half bushels, or cantles taken into the garner, because these malpractices are common. (Senechaucy, ed. Oschinsky 1971, 277).

The avoidance of any loss by unequal and unprecise measurements of harvests – or in other words: the control and maximization of profit or economic growth on a microlevel – can be ascribed one essential goal of these regulations.

A third example shows the use of tally sticks in a noble household. Around 1240, Robert Grosseteste, the Bishop of Lincoln wrote a treatise on household management for the countess of Lincoln, Margaret Lacy, after the death of her husband. Regarding the management of grain stocks, Grosseteste advised the countess to improve control of the income and harvest by the use of tally sticks.

> And then send one of your faithful household servants or valets who is to take with him the reeve of that place and another faithful man of that town-

> ship. And these three men ought to be present at all times, at the opening and closing of the granges, at the threshing, the winnowing, and at the transfer of the corn out of the grange – by tally – into the garner. And take care that no servant or bailiff receive the money of the sale of produce but only the reeve and another, who jointly will be responsible for it. (Household Rules of Robert Grosseteste, ed. Oschinsky 1971, 395) .

Beside treatises on accounting and bookkeeping in noble households, monastic houses also used tallies for the administration of their estates, as sources from the cathedrals of Gloucester and Durham show. These extracts from their respective treatises on accounting show tally use as part of the account by the bailiff:

> *Tunc clericus tradet preposito vel ballio baculum in quo ponet recepta ex una parte et deliberaciones ex altera; aut debet docere ipsum ut sciat facere talliam vel aliquod signum [curie calculatie in granario] vel alibi ut de receptis et deliberationibus secure possit irrotulare. Et sic semper erit ille prepositus in bono statu et in arreragiis non cadet.*

Translation:

> Then the cleric hands to the reeve or bailiff the tally stick on which he inscribes the receipts as well as the expenses. He also should teach him how to cut the tallies and other signs (from the accounting of the granary) or otherwise how he can write all receipts and expenses securely in the roll. Thus, the reeve will always have a good standing and will not fall into debts (arrearages).

As in noble households and husbandry, the tallies are used as a tool requiring specific knowledge of how the notches are carved (*aliquod signum curie calculatie in granario*) to store all relevant information of expenses and income of the monastery. Knowledge should be transferred by a cleric to the administrators. The income and expenses are thus carved by the bailiff respectively the reeve on either side of a tally stick. Furthermore, we learn that the information stored on the tally will then be transferred to the 'rotuli', i.e. the written account rolls. Hence in the case of clerical and monastical administration as in the other cases presented, tallies as para-literary documents helped to guarantee effective and successful bookkeeping.

The examples presented here show that medieval didactic literature on manorial administration points out very clearly the importance of tally sticks as wooden documents of control and memory alongside written bookkeeping. They were used by literate and illiterate officers involved in the control of the distribution and acquisition of resources in the context of manorial economy throughout the realm.

2.2 Tallies as evidence in court

Examples of the use of tally sticks as evidence in court draw attention to the European tradition. Here we leave England for one moment. The preservation of tally sticks together with accounts can be shown by the example of the account book of a German nobleman from 1557. This account book documents the debts of count Ladislaus von Fraunberg, who owed small sums to a baker and a butcher from Landshut. The count's creditors had sent in two tally sticks as proof of the outstanding money for consumption. In this case, they were handed over to verify the creditors' claims. Whether this was possibly done in court is not known (Liess 2000, 133).

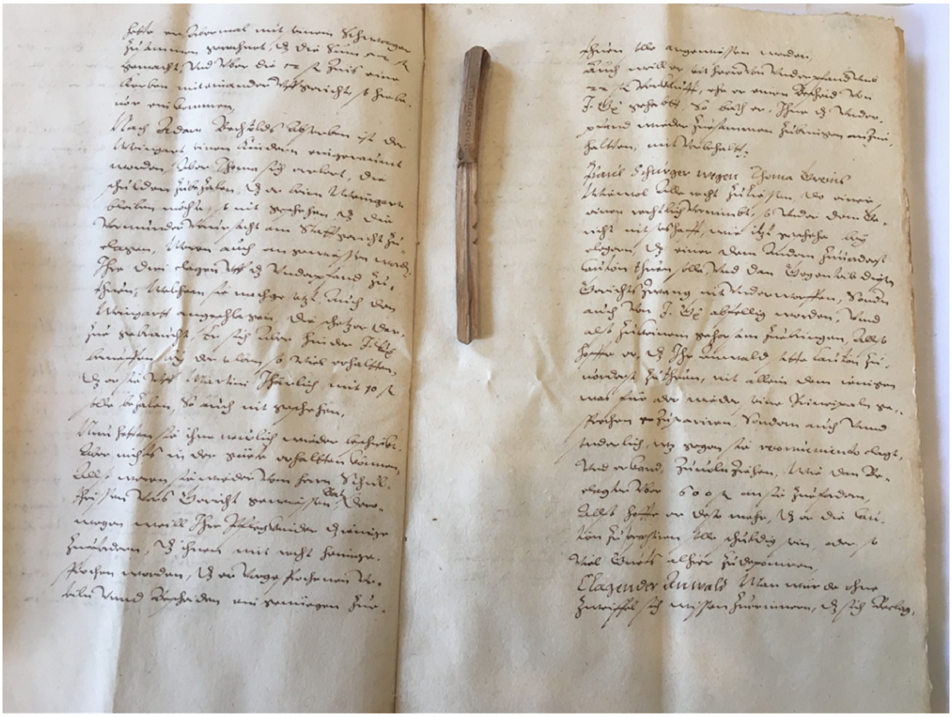
Fig. 5. **Account book and tallies of count Ladislaus von Fraunberg, 1557**

Source: Bayrisches Hauptstaatsarchiv, Kurbayern Äußeres Archiv 544, nach Blatt 314 (Schrift-Stücke 2000, 133)

Another example comes from the court protocols of the south western former county of Wertheim, close to Würzburg. Preserved in the State Archive of Wertheim these sources contain several documents including tallies from court cases, for example one from the year 1609 dealing with a court case involving income drawn from a vineyard.[1] The case that began in 1595 and lasted until 1609, dealt with the request made by the guardians in the interest of the children of late Adam Bechthold from the village of Ebenheid. The defendant Thomas Grein owed a sum of 12 guilders connected to the vineyard to the late Adam Bechtold. The acta contain a small tally stick with 12 carvings signifying the mentioned 12 shillings. Obviously both parties had made a contracts about a debt or rent from the vineyard which they had fixed in the form of a wooden stick.

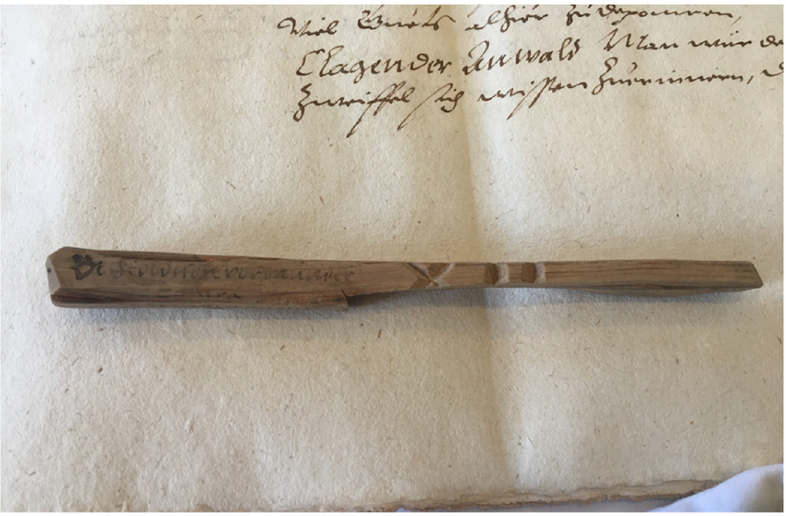
[1] Staatsarchiv Wertheim, Bronnbach, G-Rep 102 Nr. 1657.

Fig. 6. **Tally as proof in the court protocols of the county of Wertheim**



Source: State Archive Wertheim, G-Rep 102 Nr. 1657.

Fig. 7. **Detail of the same tally**



Further written evidence is available for German village courts of the 15th and 16th centuries, for example, in the so called Haderbücher from Ingelheim[2] mentioning them being brought before the judges by the villagers. Here is an example from the court protocols of Nieder-Ingelheim dated 9.6.1469:

> Hans Blanck, the baker of Ingelheim, has accused Godfart the miller of having given him bread for 22 albus each, according to the tally stick, where there is a notch for each loaf; also for 3 shillings without notches. That he did not give him the money, or acknowledges it, would cost him 4 guilders. And if he should say no to this, he would prove it to him by the tally stick. Godfart then says: He has worked off the 22 Albus. And if he accuses him further, he is innocent. The innocence is fixed for 14 days. They both had that recorded.[3]

In this case the notched wood is presented in court as evidence of bread delivered, the number of notches being equal to the number of loaves, as is pointed out. The outstanding amount of 4 guilders is claimed from the baker Hans Blank. The defendant, a miller, stressed that he had worked off the debt.

The fact that also in village communities tallies had a function as currency is pointed out by the next example from the Haderbuch of Ober-Ingelheim from 30.9.1480. It concerns a debt that was settled by means of cash and tally:

> Peter Schnade says: After he was recently sentenced to give account to Karl and Jeckel von Simmern, that is what he did. Now they were not satisfied with his account. Therefore, he refers to the brother and brother-in-law of the deceased Hans von Klee, who were present, that he delivered things to the said Hans and settled accounts with tallies and in other ways for 11 florins. And he deposited 6 guilders with the court. The aforementioned Karl and Jeckel took these against account without giving up their legal claim.[4]

The use of tallies as proof in cases of conflicts settled in courts continued throughout the centuries. In the Basel city book, tallies are still cited as legal evidence in the 18th century. And even the Code Civil (chapter 1333) still mentions the inconspicuous sticks as evidence. In addition to their role as document-like evidence in court, tally sticks advanced to become a substitute currency in England in the middle ages, thus opening up the field of pre-modern monetary and financial

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[2] With numerous examples: Ingelheimer Haderbücher Online, URL: http.//www.haderbücher.de

[3] Nieder-Ingelheimer Haderbuch 1468-1485, Bl. 045, in: Ingelheimer Haderbücher Online, URL: https://www.haderbuecher.de/baende/1468-1485-nieder-ingelheim/blatt/band-2-ni-1468-1485-bl-045/pagination/4/ (last seen 03.02.2021)

[4] Ober-Ingelheimer Haderbuch 1476-1484, Bl. 157, in: Ingelheimer Haderbücher Online, URL: https://www.haderbuecher.de/baende/1476-1485-ober-ingelheim/blatt/band-5-gw-1490-1501-bl-157/pagination/14/?L=0&cHash=768f7f0559f12795082bb72d3ea2c62e (last seen 09.02.2021)

history from the material-historical side as well, as will be shown in the following chapter.

2.3 Tally sticks as substitute for money

Tally sticks were not only tax receipts of the English Exchequer, they also played an important role as money substitute under the Plantagenet kings of the 13th and 14th centuries where they became an innovative instrument of public credit. In her monograph on English monetary history, Christine Desan traced the role of the sticks from the 12th to the 17th century and convincingly showed that they were issued by the Crown as a promise to pay (anticipation tally) like a cheque. The Crown itself acted as guarantor for this innovative form of payment order as it ensured the liquidity of money and thus the redeemability of the tallies through the continuous tax revenues. One advantage of this developing system was, of course, its independence from the still scarce coinage, in times of economic protectionism under Edward II.

How exactly this system of money orders worked has been outlined by Tony Moore in an essay (Moore 2013) on the basis of the entries in the entry rolls and the issue rolls of the treasury from the reigns of Edward I to Richard II. Accordingly, tallies were no longer issued as receipts for deposited cash sums, but were issued directly to the king's creditors for redemption with various officials in the realm. Thus, for example, an Italian banker in the 14th century could reclaim the credit sum lent to the crown directly from the collectors of royal revenues (taxes, church tithe, customs, etc.) by presenting the tally sticks. In addition, they were used as securities in secondary markets, for instance as pawns for the private loans of businessmen. Moore cites the impressive example of the financier Paul de Montefiore, who in 1343 redeemed 72 tallies totalling £7000 (which was actually to be used to redeem the king's pledged great crown) with various London financiers. Notable is the sharp decline in value. Montefiore was paid only several small sums of money for the originally valuable sticks. The state-secured securities were thus also used as collateral for private credit interests. One consequence of this development was that the treasury handled fewer and fewer cash transactions in comparison to the cashless capital transactions made possible by the tally sticks. In 1375, 30% of the Crown's revenue (£51,155 out of 165,845) was cleared in the form of tally sticks. This proportion increased even more; by the middle of the 15th century it counted for 60%. More sticks were notched and issued than coins were minted.

As a state security promoted and used by the government, tallies circulated in England's fiscal infrastructure for centuries. They were distinctive in form, fraud-proof and quite durable. By issuing them, the government controlled the number of tallies in circulation and at the same time guaranteed their redeemability, thus keeping them in demand. On the other hand, they were sometimes threatened by a sharp decline in value (up to 25%) and sale for other purposes, which not only weakened the royal finances and restricted the flow of cash to the treasury, but also signified a decentralization of the royal financial apparatus.

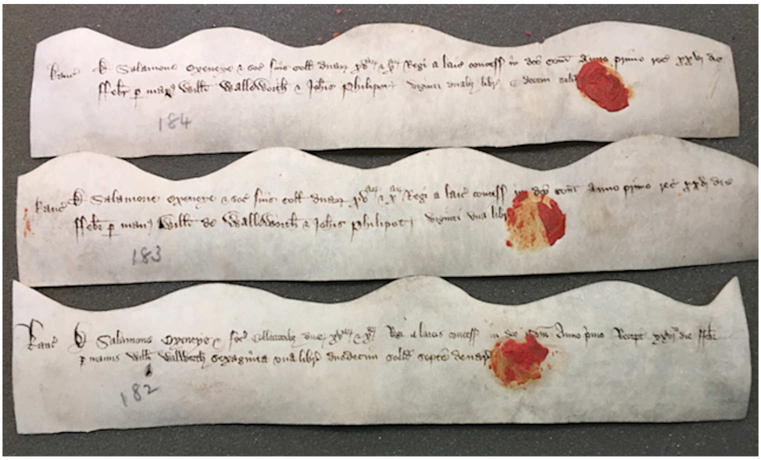
The 15th century shows an increasing regulation of the use of tally sticks as well as restrictions concerning speculation. However, they remained in use as a means of payment and credit until the 17th century. The political and constitutional instability of 17th century Britain (constitutional warfare) weakened the existing system of royal credit and led to the replacement of tallies by other forms of credit instruments, such as bills of exchange, notes and letters. This brief account shows the close connection between credit and monetary history and political control. Furthermore, one could state that the usage of tallies fostered economic growth in times of economic protectionism. The functional innovations presented here, point out the striving of political leaders for economic stability and growth and add new dimensions to the history of the tally sticks. Thus, part of their 'hidden history' becomes visible.

3. Tally sticks and written documents

3. 1 From wooden stick to parchment? Tally bills

In order to better understand the function and use of tally sticks, and in particular their relationship to written records, we need to take a closer look at their specific context of tradition. In some cases, tallies have survived together with written sources. Jenkinson for instance mentioned the impressive examples of private tallies together with parchment labels and slips of paper in linen sacks or leather bags.

Fig. 8. **Sealed tally bills (chirographs) documenting taxes collected by the sheriffs, NA, Tally bills (E 402 /4-33) (photo by the author)**



As mentioned above, tally sticks often were not used on their own, but were – especially, but not only in England – important components of a complex accounting system involving written administration as well. From the 14th century onwards, tally bills in the form of chirographs (split charters) have survived as written forms that were directly related to the tally sticks, as they contain the same information about people paying taxes and fees.

Here, the splitting of the wood is replaced by the cutting of the charter in a very specific way, which allows for proof of authenticity. In addition to this technique, the notes were stamped with the seal of the Crown. The bills were usually written in Latin, but in the NA's holdings there is also one example in French from the time of Richard II.

Most interestingly, the outline of the bills closely follows the one of the wooden sticks. The same sort of information is provided in the same order and outline, including the names of the sheriffs or bailiffs as well as of the payer, the date of collection and of course the sum collected. A closer look revealed that they seem to have been prepared as formulae and subsequently filled in. Hence, an interesting feature of tally bills is their possible classification between charter and pragmatic writing. The red seal and its chirographic exterior clearly refer to a formalized charter, the holes in the parchments point to pragmatic administrative writing that was carried along or otherwise tied in masses on a thread.

3.2 Linked semiotics: Written documents and carved tallies as complements

As became obvious in the aforementioned examples of tax and manorial administration as well as legal courts, there remain some examples illustrating tally use in agricultural production and consumption. Again, we can turn to sources from early modern southern Germany. The State Archive of Ludwigsburg holds 17 tally sticks from the 17th century.

Some of these are wrapped in paper snaps with written information about the goods' quantities documented on the sticks. Only the paper snaps enable to decipher the wooden sticks, containing notches but no writing. They for instance show us the practice of accounting everyday consumption of beer and wine and the tax (*ungeld*) paid for this comestibles. This information is provided by the paper note in which three tallies are wrapped.

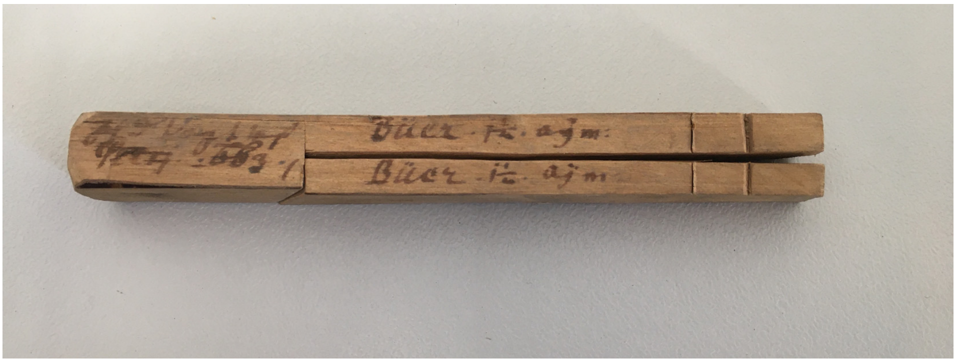
Fig. 9. **Different tally sticks from the late 16th and early 17th century in the State / Kleine Holzurkunden aus dem Limpurg-Gaildorfischen Erbschenkarchiv (1605, 1654-16636, 1692) (photo by the author)**

Source: Archive of Ludwigsburg, B 114 Bü 10197.

Fig. 10. **Writ documenting the payments of *Ungeld,* StA Ludwigsburg, B 114 Bü 10197 (photo by the author)**

Fig. 11. **Three bipartite tallies about Ugeld paid for beer and wine, B 114 Bü 10197 (photo by the author)**

Fig. 12. **Bipartite tally relating to Hans Vogt, who paid the Ugeld for one and a half buckets of beer in 1663, B 114 Bü 10197 (photo by the author)**



This bipartite tally stick documents the amount of beer consumed in the second quarter (Petri-Quartal) of 1663 by a certain person, namely one and a half buckets (1 *eimer* contained between 60 and 300 liter) as well as the name of the tax payer: H. Vogt. Both, the wood and the paper slip mark the date of accounting, but the tally marked the important information, the amount of beer for both sides.

The last example from the early modern Swabia points to an elementary problem of dealing with tallies that contain no scripture: the dependance on written documents for the interpretation or the lack of context. Looking at these tally sticks, the problem becomes clear.

Fig. 13. **Bundle of tallies wrapped in paper, B 114 Bü 10197 (photo by the author)**

Alone these sticks[5] would yield no information beside a certain quantity expressed by the notches. Only thanks to the paper wrapping as a complementary document, we learn that these wooden sticks count agricultural produce. The obvi-

[5] Staatsarchiv Ludwigsburg, B114 Bü 10197.

ous interdependence between writing and carving proves the practice of using both media as information stores, that cannot or only partly be read without each other.

Fig. 14. **The contents of the bundle, consisting of four tallies, one piece of cloth, a string and a written document, B 114 Bü 10197 (photo by the author)**

Conclusion

This paper intended to introduce readers to the broad spectrum of uses and the manifold possibilities for investigating tallies, the forgotten 'media of culture', as Axel Grandell put it. The analysis also aimed at offering new perspectives on the economic growth and productivity by approaching the important, but yet under-studied aspects of material culture and the history of knowledge. Tally sticks were used in a various contexts, simple and elaborate: as payment receipts, as markers for quantities of agricultural produce and consumables, as quasi-charters and evidence in court as well as money substitutes. The English Exchequer provides a unique picture of a sophisticated accounting system involving a class of literate laymen as financial management professionals.

In terms of their formal characteristics – the length, shape and type of carvings and the specific cuts of the wood – studies of European medieval tallies probe their great diversity, which makes it even more complicated to infer their function from their form. Therefore, the interpretation of tallies as archaeological finds can only be done in their context of transmission and a strictly comparative method must be applied. Hence, the study of tallies should involve cooperative work of historians and archeologists.

The history of signs and written culture also offers a fascinating field of research. Tallies should not be interpreted as objects *prior* to writing, but as paraliterary objects accompanying the practice of writing. Writing and carving were two different but related and often interdependent techniques of information storage in the middle ages. Their use throughout Europe lasted until the early 20th century. The longue durée of the history of tallies can be seen as evidence of their usefulness and integrability in accounting and administrative practices based on the advantage of cheap, easily transportable material, their independence from the literacy level of their users, and their resistance to fraud.

Concluding on the role of tallies for general economic growth and productivity, this paper pointed to four different contexts of tally use: bookkeeping as a vital part of an effective administration; as proofs in court and quasi-charters providing legal security of economic transactions; as an ubiquitous tool in the manorial administration to count and store grain and livestock and guarantee control over quantities of goods and labour services in partly illiterate communities, and finally as money substitute in times of coin shortage and protectionism as mean to secure the flow of capital in England in the 14th and 15th century. Thus the study of these objects might well contribute to and enrich some of the great fields and narratives of social and economic history. However, the narrative of this long history and the exploration of these fascinating objects in a broader, geographical, methodological and disciplinary comparative perspective has yet to be written.

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Carlos Fernando Teixeira Alves*

Knowledge, economy, and university in the south of Europe at the end of the eighteenth century. The case of Salamanca and Coimbra

1. Introduction

In the second half of the eighteenth century, Europe witnessed a wave of University reforms that transformed several universities (Anderson 2004; Brockliss 2003; Hammerstein 2002a; 2002b). This third wave of reforms was more impressive in Southern and Central Europe and was a remarkable response to the new mentality where Governments took responsibility for citizens' education. One of the fields in which this new outlook was evident was the teaching of Philosophy (Freedman 1999; Ruestow 1973; Stewart 1990; Martins 2013; Costa 2014; Albares Albares 2006; Fuertes Herreros 2006).

In many Universities, and Salamanca and Coimbra were no exception, we saw the introduction of the disciplines of Natural History, Zoology, Mineralogy, Botanic, Agriculture, and others. And, analyzing the study plans of the Universities of Salamanca and Coimbra from 1771 to 1820, we can conclude that these improvements eventually led to a strengthening of the disciplines devoted to the study of natural products. This investment in the introduction of subjects related to the study of natural resources of animal, mineral, and vegetable origin, meets the central interest of the Portuguese and Spanish reformers: to combat economic, industrial, and commercial underdevelopment. This vision had clear economic interests because this activity should be the necessary impulse to the productive sectors of these countries. In this way, the disciplines introduced provided the ability to identify and then cataloged and explored more effectively the various natural products from their extensive colonial territories.

The materials we study here appear in the sources analyzed as 'useful knowledge' and should be the source of economic growth, alongside measures to stimulate industry and trade. Simultaneously, scientific academies and similar institutions have gained importance and proved to be more innovative. Nevertheless, it was in the universities that the largest number of students gathered. In this work we also intend, through the cases of Salamanca and Coimbra, to try to understand if

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Referee List (DOI 10.36253/fup_referee_list)
FUP Best Practice in Scholarly Publishing (DOI 10.36253/fup_best_practice)
Carlos Fernando Teixeira Alves, *Knowledge, economy, and university in the south of Europe at the end of the eighteenth century. The case of Salamanca and Coimbra*, © Author(s), CC BY 4.0, DOI 10.36253/979-12-215-0092-9.10, in Giampiero Nigro (edited by), *L'economia della conoscenza: innovazione, produttività e crescita economica nei secoli XIII-XVIII / The knowledge economy: innovation, productivity and economic growth, 13th to 18th century*, pp. 159-175, 2023, published by Firenze University Press, ISBN 979-12-215-0092-9, DOI 10.36253/979-12-215-0092-9

the growing interest and the incentive in Natural Philosophy – through the curricula of Philosophy – attempted to solve the problems in agriculture and industry in Portugal.

This article aims to focus on the relationship between Universities and the economic development of Spain and Portugal during the second half of the 18th century. We will build on the contributions of Araújo (2014b; 2014a; 2017), Costa (2014), and Prata (2014). We also intend to dialogue with Pedersen (2002) about the expansion of the Philosophy curriculum throughout the Modern Period, starting from the cases under analysis. Frijhoff (2002), Anderson (2000; 2004), and Hammerstein (2002b) in their analysis of the University reforms of the 18th century gives us the general lines of this third wave, lines that we will try to follow in the case of Coimbra and Salamanca. With Santos (2013), Cardoso (2004), and Spary (1999), we intend to demonstrate the utilitarian and intrinsically linked character of the economy that the Philosophy curricula have shown.

In this way, I intend to divide my article into three parts: 1) identify the various subjects understood as 'useful subjects', introduced after 1771 and which are the adoption strategies followed by the two Universities; 2) compare the contents of these subjects among the two case studies; 3) try to understand if this new knowledge managed to stimulate productivity through the analysis of professional outlets.

2. The 'useful' knowledge

With the 16th century in mind, we see the emergence of an Italian school (Giovanni Pico, Girolamo Cardamo, and others) that, among other things, advocated the idea that Nature and natural products should be in line with the needs and interests of the Human being (Ingegno 2008, 236-61). In the following century, the triumph of the *mundus intelligibilis* took place. As a consequence, natural knowledge develops in two lines: knowledge of the living beings that make up the natural world; and the forces and laws that acted in this same stage (Cassirer 1992, 65-130). Understanding this tension – between practical and theoretical teaching – is important because when we reached the eighteenth century the reforms that took place sought to convey a more practical aspect where the focus was on the introduction of various materials linked to the study of Nature. In some cases, this implied profound reforms in the faculties of Arts – such as Salamanca – or the creation of new Faculties of Philosophy – such as Coimbra.

By the 18th century, studying Nature and its resources became inseparable from the concerns with economic development. In the case of the Universities under study, the idealization of the discipline of Natural History made it possible to combine these concerns. In this sense, the content of this discipline was intended to extensively teach students how to more effectively exploit the various natural products.

Tab. 1. **Medicine courses in 1771 in Salamanca and Coimbra in 1772**

Year	Salamanca	Coimbra
1º	Oldest Medical Institutions and Anatomy	Materia Medica and Art Pharmaceutica
2º	Less Ancient Medical Institutions and Anatomy	Anatomy, Surgical Operations and Obstetrical Art
3º	Prima and Prognosis	Medical-Surgical Institutions (with partial frequency in the Hospital)
4º	Vespers and Prognoses	Aphorisms (also frequently in the Hospital)
5º	---------------------------------------	First Chair of Practice (taught entirely at the Hospital)
6º	---------------------------------------	Second Chair of Practice – to reach higher degrees – (taught entirely at the Hospital)

In this way, the scientific developments in the field of Natural History kept as their goal the concrete improvement of the social and physical conditions of the population (Cardoso 2004, 15; Spary 1999, 179). With a strong emphasis on an economic component, «the close relationship between the natural order and the economic order, which leads us to the conclusion that one could not exist without the other» (Cardoso 2004, 15).

Tab. 2. **Art courses in 1771 in Salamanca and Philosophy and Mathematics in Coimbra in 1772**

Year	Salamanca – Arts[1]	Coimbra – Philosophy	Coimbra – Mathematics
1	Dialectics and Logic	Rational and Moral Philosophy	Geometry
2	Metaphysics	Natural History and Geometry	Algebra
3	Aristotelian Physics	Experimental Physics	Foronomy
4	Arithmetic and Geometry	Chemistry	Astronomy
5	Algebra and Experimental Physics	---------------------------------------	-------------------------------

The various study plans available for Salamanca and Coimbra show the importance of the subjects that are considered useful. Influenced by the University

[1] In 1771 in Salamanca, the Arts course encompassed the teaching of Philosophy and Mathematics.

reform of Amadeus II in Piedmont (Anderson 2004, 23),[2] these reforms were characterized by the adoption of more practical subjects related to Philosophy, Mathematics, and Medicine.

This change was important for European Universities. As the dominance of Theology receded, the curricular offer in other courses with a more practical component was broadened and new faculties of Philosophy and Mathematics were created in many Universities, as well as profound reforms in the curricula of medical faculties. This step was decisive so that at the beginning of the 19th century, the idea of specialization gained strength and became a determining factor. At the same time, the professors' perception of Science has changed considerably (Hammerstein 2002b, 609).

Tab. 3. **Philosophy course in 1807 and 1820 in Salamanca**

Year	**1807**	**1820**
1	Elements of Arithmetic, Algebra, and Geometry	The second course in pure Mathematics
2	Logic and Metaphysics	Natural History and Chemistry
3	Application of Algebra to Geometry	Rational Mechanics
4	Physics and Chemistry	Astronomy
5	Moral Philosophy	Optics and Acoustics
6	Astronomy and Natural History	Agriculture (bachelor's degree)
7	-----------------------------------	General History and Literary History

But despite these changes, what did this idea of useful knowledge mean? At the same time, which disciplines comprised it, and what were the goals of introducing this type of knowledge?

It is during the Renaissance that we see a greater appreciation of this utilitarian aspect. The perception of Natural Philosophy becomes tripartite: speculative, active, and factive or constructive (Wallace 2008, 210). The latter, also known as Mechanics, was divided into Arts, Useful Disciplines, and disciplines that provided pleasure (such as Music). The Arts and the Useful Disciplines contained more practical subjects. For example, the Arts included subjects such as Agriculture and Navigation. However, one aspect seems to be essential in the definition of useful, its connection with the study of Nature. And in this respect, the study plans introduced in Coimbra and Salamanca are a good example of a more utilitarian vision of Nature and its resources. Mainly, what they show us is that in the second half of the

[2] For the Italian case see (Carpanetto e Ricuperati 1987; Ricuperati 1973; Ricuperati and Roggero 1977; Roggero 1987; Del Negro 1991).

18th century we already have different empirical approaches to studying Nature. In this way, various disciplines emerged.

Tab. 4. **'Useful' knowledge introduced in Coimbra and Salamanca, 1771-1820**

Disciplines
Experimental physics (Philosophy)
Materia Medica and Art Pharmaceutica (Medicine)
Natural History (Philosophy)
Botany (Philosophy)
Chemistry (Philosophy)
Zoology (Philosophy)
Mineralogy (Philosophy)
Agriculture (Philosophy)
Metallurgy (Philosophy)
Hydraulics (Philosophy)
Astronomy (Mathematics)

As we can see (Tab. 4), the study of natural resources in the curricula of Coimbra and Salamanca was translated into more than a dozen subjects that were divided among the courses of Philosophy, Mathematics, and Medicine. Through these disciplines, we can also see that this utility was based on the exploitation of various natural resources.

Although, it is perhaps in the Philosophical faculties that this sense of the useful was felt most.

In 1801, the Portuguese authorities issued a royal charter that provided for significant improvements in the teaching of Natural Philosophy, and proved to be a considerable strengthening of the 1772 proposal: «[…] it is appropriate to apply the lights of Natural Philosophy to the discovery of the immense riches and treasures, which Nature has liberalized with My Kingdoms and landlords [...]»,[3] thus promoting the exploitation of products from the various areas of the Portuguese colonial space, in order to develop the productive sector (in agriculture and manufacturing), similar to other European countries.

In Salamanca, a few decades later, we witnessed a new change in the scheme of disciplines that studied Nature; which then had two groups of disciplines. The first group of subjects was to be dedicated to the study of Nature and included subjects such as Cosmography, Natural History, Zoology, Botany, Mineralogy, Physics, and Chemistry. The second (Natural Sciences and Useful Arts), included Rational Mechanics, Astronomy, Optics and Acoustics, Agriculture, and Arts and Crafts.[4]

[3] Arquivo da Universidade de Coimbra (AUC), *Legislação Académica*, 1772-1824, IV-1° E 8, Tab. 3, n°4, 127v.-128. Translated from the original by us.

[4] *Informe de la Universidad de Salamanca. Sobre Plan de Estudios, ó sobre su fundacion, altura y decadencia, y sobre las mejoras de que es susceptible: con cuyo motivo presenta un proyecto de Ley sobre la Instruccion Publica* 1820, XXIV.

In this way, we see that this idea of the 'useful' is linked to various fields of knowledge that studied (Cardoso 2004, 14), for the most part, Nature, and rational ways to exploit its resources.

3. The content of the new disciplines

Of the various disciplines introduced in the Universities under study, we have chosen to focus on the most important ones, which were a significant novelty with the teaching taught since the early 18th century. We are therefore talking about Natural History, Botany, Mineralogy, Zoology, Agriculture, and Chemistry. These disciplines were, as we will show, the central point in a strategy that aimed to change the teaching of Philosophy, to train specialists in the area of natural resource exploitation. In this way, the Portuguese and Spanish reformers tried to overcome a situation of economic backwardness throught the exploitation of natural resources. But let's start with the Natural History subject[5].

This discipline was introduced at different times: in Coimbra in 1772 and Salamanca in 1807 (Addy 1966). But despite the time difference, its content was very similar, and with a clear practical component. In Coimbra, it was taught in the second year of the philosophy course and was understood as a basis that students had to acquire to continue their studies in physics and in «[...] all the Arts [...]».[6]

The study of Nature in Coimbra had its high point with the creation of the subject of Natural History. This matter had two main objectives: «[…] to make an exact description of each one of Nature's products: Second, to collect the substance of all the observations […]». The exposition on its content should start with Zoology, Botany, and only then Mineralogy. Not only in Natural History but also in Chemistry itself, there is one obvious characteristic: the choice of the products used in the lessons, of which the students had to have vast and precise knowledge, would have to be based on their utility – the utilitarian aspect, for commercial and economic exploitation purposes. This argument had a greater presence in Coimbra's curriculum. Thus, «[…] the Animals[…]» that could be commercialized or useful in agriculture (or other economic activity), were important for Zoology. The link between human needs and natural products should be essential for any student who wanted to graduate in Philosophy. For instance, in Botany, should be prioritize, 1) the knowledge of plants and 2) their use, privileging direct experience.

The major changes in the curricula – where philosophy's study of nature was an essential part – that occurred in 1772 were the direct consequence of the will of the central authorities to encourage a more effective exploitation of colonial wealth (Santos 2013):

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5 For the evolution of this discipline in the period in question, see (Browne 2003; Cook 1996; Dear 2006; Drouin e Bensaude-Vincent 1996; Farber 2000; Findlen 2006; 1996; French 1994; Guntau 1996; Jardine 1996; Koerner 1996; Larsen 1996; Roche 1996; Sloan 1996)

6 *Estatutos da Universidade de Coimbra (1772)* 1972, Livro III: Cursos das sciencias naturaes e filosoficas: 239-44. Translated from the original by us.

> […] the challenges opened by the exploitation of colonies [...] the need for a strong administration and a properly qualified technical staff [...] have [...] contributed to the political decision and introduce deep reforms in education […].[7]

In the case of Salamanca, in 1820, we identify the same idea of defending the relationship between agriculture and the development of commerce and industry (the real reason for the introduction of this chair in the University) – «[…] will establish the teaching of Practical Agriculture: and for this, in attention to the present state of the Nation […]».[8] In the same mindset was the professor at the University of Coimbra, Avelar Brotero, in 1824, when he stated that this relationship is fundamental, also adding more disciplines, such as Zoology, Botany and Mineralogy «[...] because of their great use […]»[9] in areas such as medicine and trade.

However, in the case of Coimbra, we witnessed an interesting phenomenon. Two decades after the introduction of the chair of Natural History, we witnessed a fragmentation that led to a proliferation of new knowledge. Thus, we gradually began to have Zoology, Mineralogy, and Botany, taught autonomously, for some time. The rapid evolution of this knowledge forced the University authorities and even the central power to act several times to create new disciplines. However, we also saw that these new creations kept much of their content, although with some updates.

Early in Botany, the study of plants was circumscribed to their usefulness, not only commercial but also medical. In Salamanca (1799), this subject was mainly linked to the study of Medicine. But in Coimbra (c.1790), the offer was broader; students not only had to study plants for medicinal purposes. This was because the connection between Botany and Medecine, although stimulated and necessary, was considered not the whole, but only a part of a philosophy student's learning. And Coimbra, since Botany moves away from natural history, it seems to have been associated with another, of Agriculture[10]. This situation continues until c.1800, when it returns to its original form and is taught in conjunction with Natural History. This change occurs after several complaints from teachers, as in 1792. Professor Luís António de Sampaio believes that Botany and Agriculture should not be taught together due to their content: «[...] as they are very different sciences dependent on several principles that should be treated separately [...]».[11]

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[7] Translated from the original by us.

[8] *Informe de la Universidad de Salamanca. Sobre Plan de Estudios, ó sobre su fundacion, altura y decadencia, y sobre las mejoras de que es susceptible: con cuyo motivo presenta un proyecto de Ley sobre la Instruccion Publica* 1820. Translated from the original by us.

[9] AUC, *Processos de Professores*, Cx. 26. Translated from the original by us.

[10] Arquivo Nacional da Torre do Tombo (ANTT), *Ministério do Reino. Instrução. Requerimentos da Universidade de Coimbra*, 1778/1799, Mç. 504, Cx. 628.

[11] ANTT, *Ministério do Reino. Instrução. Requerimentos da Universidade de Coimbra*, 1790/1795, Mç. 502, Cx. 602. Translated from the original by us.

The discipline of Agriculture does not appear in Salamanca until 1820. And with an identical content, which demonstrates its importance for the development of the country: «What is there to learn scientifically this most useful art to all nations, and especially to fertile Spain [...]».[12]

In the case of Zoology, since 1772 in Coimbra, while it was still included in natural history, its goal was to provide students with knowledge of animals that could (for various reasons) be traded or used in Agriculture. Instead, Mineralogy almost always ended up being linked to other sciences. However, its study should focus on the study of the various soils and minerals, and their best use. Later on (c.1800), these two disciplines keep their content and was taught together.[13]

Of the various subjects we have seen above, one aspect stands out, the study of various natural products. However, not all products were of interest, regardless of their origin, vegetable, mineral, or animal, in Portugal and Spain the criterion for choice would be the usefulness of these products. The objective was a rational and efficient exploration of these products, in a logic of modernization and stimulation of the commercial balance (Costa 2014, 181-84).

This group of disciplines, however, excelled at identifying and characterizing the various products and their purposes. But to complement this group another discipline was needed, dedicated to the transformation of mainly plants and minerals, we are talking about Chemistry. Miguel Bernardes, a Spanish physician, in 1767 had already demonstrated the importance of Chemistry for the study of natural products. In one of his letters, we see that the richness of this science lies in the versatility that will provide his students with the ability to transform products: «[...] the particular nature and action of natural bodies, be they water, minerals, plants, or animals [...]».[14]

At the university of Coimbra, its introduction dates back to 1772 and at Salamanca in 1799. In the Portuguese statutes, this discipline was considered the third part of Natural Philosophy. At this university, conducting experiments was a very important component, where even a mandatory number of practical classes was stipulated. However, the big difference was in the products used in class. In Coimbra, saline, metallic and liquid products should be used, therefore, from a much more varied range; while in Salamanca, we note that, as with other disciplines, chemistry was also very much geared towards the teaching of Medicine, therefore, the products used in the classroom would only be those that could have medicinal purposes.

The case studies we have seen are an excellent example of a strategy that thought of universities as agents of transformation and change, with the aim of

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[12] *Informe de la Universidad de Salamanca. Sobre Plan de Estudios, ó sobre su fundacion, altura y decadencia, y sobre las mejoras de que es susceptible: con cuyo motivo presenta un proyecto de Ley sobre la Instruccion Publica* 1820, 56. Translated from the original by us.

[13] AUC, *Registo das cartas de provimento da Faculdade de Matemática e de Filosofia*, IV-1º E 8, Tab. 4, n.º10-A.

[14] Archivo Historico Nacional (AHN), *Consejos, Universidades*, *Legajos* 5459-nº6. Translated from the original by us.

preparing a concerted response to the needs of society. More precisely, in the fight against the economic backwardness of Portugal and Spain. This economic aspect linked to physiocracy (Escartín e Velasco Morente 2009; Lluch 1996a; 1996b; Lluch and Argemi 2000; Cunha 2011; Nokkala e Miller 2019) was essential in the reforms under study. Which demonstrates the intrinsic link between physiocracy and the management of trade and finance. With the 18th century, Monarchs and Ministers began to support not only the study of Nature but naturalists themselves. In this way, we see a kind of science of natural economy (Spary 2000, 13).

4. The problem of the employment between philosophers

The investments made in curriculum reform and the construction of various scientific equipment, such as laboratories, have been impressive. In the pedagogical and scientific area, we conclude that, in relation to a previous situation, and in comparison with other reforms in Europe, Coimbra and Slamanca, at different stages, have achieved significant improvements (Alves 2021). However, independently of these transformations, it was impossible to solve another problem: the professional future of philosophy students[15]. In this aspect, the Universities of the Holy Roman Empire achieved significant advances. Hala, but especially Göttingen, stood out in this period (Hammerstein 2002b, 606; Turner 1974). Its faculties of philosophy played a very active role, ensuring similar privileges to other faculties. This ensured jobs that were later filled by philosophy graduates. In fact, this seems to have been the 'solution' followed by several countries, including Portugal and Spain. Although, with different results. Let's take a closer look at the Portuguese case.

The decline of the Portuguese economy has been evident since 1780, despite the greater integration of the primary sector in international trade and the importance of the Empire; however, it was strongly marked by two decisive moments: the earthquake of 1755 (which destroyed the fixed capital in many regions) and the French invasions (in a period where a recession was already visible due to the decline of gold extraction) (Costa, Lains and Miranda 2016, 164-65). Sectors such as the agricultural sector, despite the great diversification of crops, a result of market incentives that positively affected the standard of living until at least 1760 (Palma and Reis 2016), still showed a very low capacity to innovate (Costa, Lains and Miranda 2016, 164-85). At the same time, the industrial sector benefited from pressure from national authorities, which allowed, «[…] promoting new forms of organizing labor with good results in exports manufactures to colonial markets.» (Costa, Lains e Miranda 2016, 164-85). From 1630 to the mid-18th century, and despite some phases of decline, the Portuguese economy grew steadily, in terms of income per

[15] In the royal charter of June 9th, 1801, a detailed plan already appears concretely, aiming to guarantee professional outlets for graduates in mathematics, linked to commerce and industry, Repositório Digital da História da Educação, Legislação, Século XIX, *alvará de 9 de Junho de 1801*, http://193.137.22.223/fotos/editor2/RDE/L/S19/1801_1810/1801_06_09alvara.pdf.

capita and population, leading to the Portuguese Gross Domestic Product (GDP) in the 1750s being larger than other European countries, notably England and Holland (Palma and Reis 2018, 3). However, starting in the 1750s, and despite population growth, the portuguese economy dropped considerably until the middle of the 19th century (Palma and Reis 2018, 3-4).

But, with a new training, both in philosophy and mathematics, where could these new graduates find their jobs, in order to help these countries overcome their state of economic stagnation?

It is possible, that this decline may have limited the professional aspirations of the few philosophical students graduating from the University. In this way, the lack of jobs available for philosophy graduates was even considered one of the reasons for the failure of this reform. The great obstacle would be the inability to absorb these graduates, due to the same backward situation that was to be fought against: «Both the Mathematics and Philosophy graduates, true levers through which the country's development should pass, had nowhere to be professionally placed [...]» (Prata 2014, 344-45).[16] Another consequence of this difficulty is the reduction in the number of students enrolled in the philosophy course (Alves 2021, 109; Vasconcelos 1941, II: 111-40).

The Portuguese authorities had to intervene, although without much success. Initially, the option seems to have been directed at attracting new students, through funding for those who wanted to study. The rector at the time, Francisco de Lemos, was quite active in putting forward measures to secure places for philosophy students (Lemos 1980, 106). However, these measures had been insufficient. In 1781, we have another missive where it is indicated that it was necessary to ensure more professional opportunities: «[...] the same Privilege must be expanded, since experience has shown that it is not enough to attract listeners to the Philosophical Faculty [...]».[17] In essence, this request was intended to ensure that these students after their training could be admitted to the subject of Rational and Moral Philosophy, which would then be taught in secondary schools.

However, despite some concrete measures, the results were still insufficient. But let's continue to look at the Portuguese case, the most enlightening. In 1811, a well-known philosophy professor, more precisely of the chair of metallurgy, delivered a broad reform plan for the philosophy course. In this proposal, the professor enumerated many of the difficulties that this faculty faced at the beginning of the 19th century. However, one problem seemed to be already endemic: the lack of jobs for philosophy graduates[18]. But unlike before, this time the proposal for possible places for philosophers has gradually increased. If before, the actions taken were mainly aimed at teaching positions, José Bonifácio de Andrade intended to change this paradigm. He quickly concluded that what would attract students to the Phi-

[16] Original translated by the author.

[17] ANTT, *Ministério do Reino. Instrução. Consultas do Concelho de Decanos da Universidade de Coimbra*, 1779-1831, Mç 517. Cx. 643. Original translated by the author.

[18] ANTT, *Ministério do Reino. Instrução. Consultas,* Mç 517. Cx. 643.

losophy course would be the «[...] lucrative and honorable jobs, to which he could legally aspire [...]».[19]

Contrary to other European states, which in the teacher's opinion were already benefiting, in Portugal, the lack of articulation between the course in Philosophy and the future of these philosophers was still real. Thus, for the first time, a proposal emerges that contemplates concretely the initial ambition for the construction of a new philosophy course, and the introduction of new subjects such as Natural History, with the impotence of having individuals with a Philosophy background working in key areas of the economy.

The list presented is extensive, but it covered three essential areas: industry, administration, and commerce. For example, in the area of (public) administration, the positions of secretaries of the overseas governments, intendants of the provincial arsenals, mint scales judges, or even directors of the senate of Lisbon, should be occupied by philosophy students.

However, it was in the area of commerce and industry that the professor's contribution was most interesting. The positions to be occupied by philosophers were deeply related to trade with the colonies. In this aspect, the positions reserved for philosophers would be mainly: deputies of the sugar inspection board, customs judges in the provinces, judges of the balance of the mints and judges of the general casting of the mints, or even director of the tobacco customs. These are only some of the suggestions of the Philosophy professor, but it shows, finally, a concrete plan that was articulated with the teaching that the philosophy faculty was providing after the reform of the studies of 1772.

But this contributor also understood the need to secure places in the industry. For example, inspectors of mines, smelters, and metal factories, superintendents of county factories, and also directors of the management of the silk and water works.

The link between economic growth and the absorption of Philosophy (and Mathematics as well) graduates is an aspect that deserves further study, even involving a more detailed study of their career paths. However, two ideas seem important. First, the reforms of the Philosophy course coincided with a period of decline in the Portuguese economy. The reforms in education (including the University) were one of the responses to this reality, although with little effect. Second, the articulation between Philosophy graduates and the industrial and commercial sectors was practically nonexistent, despite the various proposals in this regard.

5. Conclusion

In this paper, we have seen how an economic development strategy is based on educational reform. To this end, new courses and new disciplines were devised to provide new and more effective ways to exploit the abundant natural resources in Portuguese and Spanish colonial spaces. In this sense, it was the Philosophy course

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[19] Original translated by the author.

that best reflected this strategy; and it was this course that served as the 'home' base for useful knowledge. This definition was considerably broad. The various disciplines that were considered useful were divided among the courses of philosophy, mathematics, and medicine. But despite this, what is clear is that all of these disciplines were devoted to the study of natural resources.

Of the set of disciplines introduced in Coimbra and Salamanca in the second half of the 18th century, the most relevant was Natural History, Botany, Mineralogy, Zoology, Agriculture, and Chemistry. In Coimbra, Natural History had two main objectives: firstly, to identify and describe natural products with economic potential and, secondly, to initiate the observation and collection of information on these products. The content of this course encompassed the three 'kingdoms' of nature, which means that the lessons dealt with products of animal, plant, and mineral origin. At the University of Salamanca, the content of Natural History was similar, the only change was the introduction of Astronomy (Addy 1966, 373). However, in 1820, Astronomy was replaced by Chemistry.

The chair of Natural History and its evolution well demonstrates the rapidity of scientific developments at the time. This chair quickly gave way to other disciplines. Botany was perhaps one of the most important. In Salamanca it was aimed at medical training and in Coimbra it was linked to the chair of Agriculture (briefly); its objective was similar in both universities: the study of plants and their usefulness. Although, in Salamanca, the plants studied in the classroom were mainly for medicinal purposes.

In turn, Zoology and Mineralogy were the disciplines that complemented the study of the other 'kingdoms' of nature: the study of resources of mineral and animal origin. In Agriculture, the students had a more complete overview of soils, seeds, and the best methods of cultivation. In Chemistry, the students put into practice much of the knowledge acquired previously, this time in the transformation of the products.

The extensive curricular transformation, and the varied pedagogical offer that emerged after 1771 in Salamanca and 1772 in Coimbra, were indeed innovative. Compared to the teaching that would have been in place before these reforms, we have seen considerable pedagogical and scientific advances. However, in the broad plan of industrial and commercial reform, the capacity to absorb the new philosophy graduates failed. The difficulties in getting a job where they could apply their knowledge was often insurmountable obstacle. As in many universities, the solution seems to have been the use of decrees to secure philosophy students some jobs.

The Portuguese case is exemplified. Since 1772, several reports, mainly from university professors, state that enrollments decreased considerably, one of the causes being the lack of professional opportunities. However, many of the measures did not achieve the desired results, and it was only in 1811 that we had a concrete plan. José Bonifácio de Andrade, professor of Metallurgy, designs three areas where Philosophy students should be integrated: industry, administration, and commerce.

The metallurgy professor's plan did not have a practical application. In practice, this led to a continuation of the problem.

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Maarten Prak, Patrick Wallis

Transferring useful knowledge. Quality mechanisms in European apprenticeship

1. Introduction

Between roughly 1400 and 1800, Europe experienced a slow but in the long run significant process of industrial product and process innovations. Blinded by the light of steam engines and spinning jennies, historians and economists have long associated innovation with break-through inventions. At the same time, they tend to portray pre-modern crafts as inefficient and hostile to innovation. The Applied Arts of the period suggest a very different story: museums hold numerous objects that show an increased capacity on the part of their makers to improve their products to an astonishingly high quality.

Clockmaking was one such craft. In addition to illustrating the potential for technological advances, it is also one in which we trace in detail some of the steps in the process by which innovation spread (Kelly and O'Grada 2016; 2022). In the later seventeenth-century, much of the improvement in European clockmaking was occurring in London, where natural philosophers such as Robert Hooke were working in collaboration with highly skilled artisans such as Thomas Tompion, George Graham and William Clement to develop new types of escapement and spring that allowed for greater accuracy. Clockmaking offers a powerful example of the collaboration between natural philosophy and an upper-tail of skilled artisans that Joel Mokyr and others have emphasised as a key ingredient of the long process of industrialisation (Mokyr 2009; Kelly, Mokyr and O'Grada 2014).

Why was this group of highly skilled artisans available? We can take Thomas Tompion as an illustration. Tompion was a leader in his field: he supplied clocks to the Royal Observatory that employed a new escapement, designed by Richard Towneley, that only needed to be wound once a year. Tompion also produced some of the first watches that used balance springs, devised by Hooke. The first step in this career began while he was a teenager, when Tompion was bound as an apprentice and moved to London to train from a small village in Bedfordshire. His presence in the city was a product of an institution that allowed his family to invest in his human capital and mobility.

The contribution that apprenticeship made to economic and technological development in pre-industrial and industrialising Europe has been noted by a number of authors. However, in this paper we investigate a specific element of

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Referee List (DOI 10.36253/fup_referee_list)
FUP Best Practice in Scholarly Publishing (DOI 10.36253/fup_best_practice)

Maarten Prak, Patrick Wallis, *Transferring useful knowledge. Quality mechanisms in European apprenticeship*, © Author(s), CC BY 4.0, DOI 10.36253/979-12-215-0092-9.11, in Giampiero Nigro (edited by), *L'economia della conoscenza: innovazione, produttività e crescita economica nei secoli XIII-XVIII / The knowledge economy: innovation, productivity and economic growth, 13th to 18th century*, pp. 177-192, 2023, published by Firenze University Press, ISBN 979-12-215-0092-9, DOI 10.36253/979-12-215-0092-9

qualitative improvement that has so far been overlooked in the literature: the selection of teachers by apprentices. As we will demonstrate, this selection was far from random. Previous authors have already observed that many masters apprenticed few or even no youngsters at all, while others trained many apprentices. We combine this observation with a second: those training many apprentices were usually the most skilled and successful masters in their trade.

We argue that this selection process provided a Darwinian mechanism of quality improvement in the pre-modern industrial sector. Apprenticeship was high-skill biased. A disproportionate share of young workers received their training in the workshops of the leading practitioners of their crafts and trades. What mattered was not just that Tompion was himself once an apprentice, but that, as one of the leading figures in his trade, he would, in turn, train at least 23 apprentices in his workshop between 1673 and 1699.[1]

Before we present our evidence, we need to explain how the transfer of industrial skills worked in the past and how it might have contributed to innovation. Our analysis proceeds in several steps. First, we argue that innovation by skilled workers was particularly important in pre-modern contexts and that the contexts in which it occurred relied on importing labour, not reproducing skill within the family. Second, we summarize the key institutional frameworks within which apprenticeship operated, identifying the importance of contract law and the more complex contribution of guilds. Third, we set out our model and key predictions. Fourth, we provide evidence to show that the patterns of concentration of training and the connection between training and skilled masters in England and the Netherlands are consistent with the idea that in early modern Europe training was biased towards transferring high quality skill between generations of workers in a way that helped sustain incremental innovation and development.

2. Innovation and Human Capital

Innovation is defined for this paper as «the multi-stage process whereby [producers] transform ideas into new/improved products, service or processes, in order to advance compete and differentiate themselves successfully in their marketplace» (Baregheh 2009).[2] Various types of innovation can be, and have been, distinguished, but most studies of innovation concentrate on two in particular: product and process innovations. Product innovations concern changes in the output; these include design, quality, price, and so on. Process innovations concern changes in the way that the output is produced; these include division of labour, tools (including machinery), volume, and so on (Fagerberg 2005). Both types of innovation occurred across most sectors during the centuries before the industrial revolution.

Famously, economist Joseph Schumpeter portrayed innovation as a process of «creative destruction» resulting from dedicated efforts that led to new technologies

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[1] Tompion's career is well summarized in the *Oxford Dictionary of National Biography*, s.v. 'Thomas Tompion'. Tompion's training career is reconstructed from the guild records.

[2] To reflect pre-modern conditions, the definition has been changed by substituting «producers» for «organizations».

replacing older ones (Ruttan 1959). In a classic paper on the topic, Nelson and Winter have, however, pointed out that much innovation can be «evolutionary», and a «stochastic» (i.e. randomly determined) process (Nelson and Winter 1977; also Nelson and Winter 1982). Their approach downplayed the importance of formalised R&D and inventions, and underlined the small, but in the long run significant innovations introduced by workers within the production process itself; think of the on-going improvements in motor cars (Dosi and Nelson 2010). As this research shows, much innovation is the result of attempts, often anonymous, for improvements, rather than resulting from dedicated research.

This model of innovation foregrounds the role of workers instead of science as a crucial source of progress. Obviously, R&D efforts have contributed significantly to innovation, but they are not the exclusive source of either product or process innovation. Today, this applies especially to small and medium-sized enterprises, unable to afford their own R&D facilities. The small role for formal scientific enquiry, the link to the small size of firms, and the lack of dedicated research all provide reason to believe that incremental, evolutionary and stochastic innovation by workers is the most appropriate way to understand the situation before 1800 (Epstein and Prak 2008). The balance between the drivers of innovation changed in the nineteenth century; before, innovation is seen as the outcome of trial-and-error by producers; after, it became more often the result of dedicated efforts, informed by science. In modern terms: it was human capital that made the most difference to innovation before the Industrial Revolution.

In fact, we can go further. The contribution of skilled artisans' human capital to premodern innovation was also essential to the limited amount of «science»-led innovation that occurred in this period. Their supply of manual skills served as an essential complement to cognitive knowledge, enabling the implementation of early science-based innovation. This process has been emphasised heavily in recent work by Joel Mokyr, and his arguments naturally centre on the availability of an abundant source of highly skilled artisans in relevant sectors, such as clockmaking and metalwork (Mokyr 2009; 2020).

Many of these effects are the unintended outcomes («spillovers») of interactions between practitioners. Nowadays, we can observe them in Silicon Valley, but they were probably as relevant during the Italian Renaissance, or indeed the Industrial Revolution. Well-known examples are the Venetian glass industry, Lyon's silk industry, and watch-making in the Swiss Jura. Clustering was a general feature of premodern urbanisation. In early modern London, for example, various crafts used to be concentrated in small pockets of the city. Quite how artisans innovated within these clusters is, unfortunately, in many ways still a mystery (Prak and van Zanden 2013). What is clear, however, is that innovations in clusters occur as a result of collective efforts, in locations with relatively high densities of craftsmen that are open to new knowledge and new people, and possess facilities for high quality training.

The importance of these two factors - skilled workers and clustering - had critical consequences for innovation in premodern Europe. On the one hand, the importance of incremental improvements made within workshops meant that much innovation was embodied, in the sense that the product or process was not fully articulated into prescriptive knowledge. Spreading innovations therefore relied on spreading skilled workers, as S.R. Epstein and others have argued (Epstein 2013). The movement of people between different leading centres served both to transmit practices and ideas and to cross-fertilize between them in a way that further advanced knowledge, while movement between leading centres and producers in other locations allowed new ideas to spread out gradually. This process of knowledge exchange and diffusion through migration is visible in a number of industries, from beer brewing to silk weaving.

On the other, the harsh demographic realities of premodern towns and cities meant that clusters were inherently unable to sustain themselves through natural replacement. Artisans could not rely on drawing on workers from within their family. Maintaining a skilled labour force, let alone expanding, instead depended on importing workers. While some of these workers might arrive with skills, others would need to be trained. Viable clusters needed to be centres for training, in short. They therefore needed a framework through which training could be organized. In the absence of large firms that might train workers over a career, apprenticeship provided this framework.

3. Skills and training: apprenticeship and premodern Europe's institutions

One of the implications of the tacit character of craft skills is that they can only be acquired through inter-human, person-to-person interactions. Aspiring craftsmen have to learn their trade from experienced practitioners. The traditional – and perhaps also original – setting for such transmission is the household. Almost as fundamental is apprenticeship, observed in diverse societies around the world as a way of exchanging training for labour.

In premodern Europe, apprenticeship connected with three distinctive and connected institutions. The first is contract law, particularly the legal instrument that allowed the master and apprentice and family to agree an employment contract that combined service and training. The second is the system of courts, especially urban tribunals, that offered a way for both parties to address problems that developed during contracts. The third are the guilds that assimilated apprenticeship into their selection systems, adding an incentive to seek apprenticeship and providing some monitoring, quality control and certification to it.

In an important recent paper, De La Croix, Doepke and Mokyr set out a model in which guilds offer a middle stage of enforcement situated between the clan, in which human capital is transferred within limited kinship networks, and the modern market in which access to training is open to all (De la Croix, Doepke and Mokyr 2018). The effect of the guild is to widen access to skill by providing a system for local enforcement of contracts in specific occupations and towns. However, the institutional evolution they present does not match historical developments in Europe, at least, where open contracting for apprenticeship preceded guilds, and local courts were the key institution for enforcement.

The earliest records of apprenticeship in Europe are legal contracts for service, surviving in Genoa and a few other cities with early notarial archives (S.A. Epstein 1991). Contracts remained fundamental to apprenticeship into the nineteenth century. In some places, as for instance medieval Genoa or early modern Paris, these were notarial contracts, which would still be phrased in quite general terms, requiring the master to share «the secrets of the trade», or «mystery of the craft», with his apprentice (S.A. Epstein 1991, 63-76; Kaplan 1993, 437-41). Such contracts also spelled out such details as the amount of money the apprentice's parents or guardians were paying for the boy's education, as well as his room and board. In others, contracts were oral agreements, or relied on simple printed forms that set out standard terms. These contracts, however, presupposed the existence of a regulatory framework for enforcement.

This framework was found in Europe's courts, particularly its urban courts which oversaw the largest populations of apprentices, and which possessed the legal authority to oversee and adjudicate disputes over contracts of this kind. We have substantial evidence that urban courts were at the centre of enforcement in many centres for training in Europe, including England, Venice, Madrid, and Turin (Prak and Wallis 2019). By the sixteenth century, these were often tribunals with specialized jurisdictions in which apprenticeship had a specific place.

What about the guilds? European guilds from very early on assumed responsibility for apprenticeship and helped shape the system (Prak and Wallis 2019). However, craft guilds combined a variety of roles (Prak, Lis, Lucassen and Soly 2006; Kluge 2007; Epstein and Prak 2008). They worshipped the patron saint together. They lobbied local governments for legislation favourable to the trade. They sometimes accepted responsibility for public services like firefighting or militia duties. To improve their bargaining position, and perhaps to also make life easier for their members, they attempted to restrict access to the craft to their members only. The regulation of apprenticeship was only one of the roles that many guilds took on, and the way guilds influenced training intersected with these other roles.

At a more basic level, guilds also incentivised entry to training. We know that the apprenticeship was not required by all craft guilds at all times, but so far the indications are that completing training became the normal route to membership in many guilds. It has been established for seventeenth-century England that more than half of all apprentices failed to complete their training contracts. However, those who aspired to open a workshop and thus had to acquire membership of a guild, almost invariably did so. As a result, those in charge of industrial workshops in seventeenth-century English towns had spent a substantial period – at least seven years – in training and at least some had ended this by demonstrating their skill by producing a sample product to the satisfaction of the examiners. Those who dropped out earlier, usually three of four years, must have acquired a reasonable amount of expertise along the way, even if they were not able to obtain the certificate (Wallis 2008, 839; Minns and Wallis 2012).

Guilds also frequently imposed quotas on the scale of training that any individual master could offer. Usually, this took the form of rules on the number of apprentices they could employ in any period. This set of regulations was rarely a binding constraint, as we will see. However, it did serve to limit the degree of concentration we will discuss below, and so reduced the visibility and the impact of the pattern of high-skill biased training that we discuss below.

We should be clear that guilds did *not* regulate the contents of the training as such. S.R. Epstein has suggested that guild regulation was needed to overcome the imbalance between the interests of the apprentice (who was learning the craft during the early stages) and the master (who stood to profit from the apprentice's labour during the later stages of the contract). Given the number of drop-outs observed in early modern cities, this cannot have been more than one part of the explanation (Wallis 2008, 853-54; Schalk et al 2017). The fact that both the regulations and the meticulous registration of apprentices seem to prioritise the administrative side of the education suggests two things. First, that contemporaries may have found it difficult to articulate tacit knowledge which was also subject to changes as industries innovated. However, it is more likely that the guild's primary responsibility was to make sure that apprentices' education as such was properly recorded. The outcome would have been covered by the final exam constituted by the requirement to produce a master piece, if there was one, or by the market if there was not.

Before, and even during the Industrial Revolution, apprenticeship was a distinctive and massive phenomenon in Europe. Perhaps in Europe as a whole as much as 25 per cent on average of all boys, and quite a few girls as well, passed through the corporate apprenticeship system. Apprenticeship is therefore a likely element in the explanation of industrial development before the Industrial Revolution. There can be no doubt that it was essential to the *reproduction* of skill. However, we still have to establish the channels through which apprenticeship contributed to the *advancement* of skill – to innovation.

3. Apprenticeship and the development of skill

The example with which we began of Thomas Tompion's combination of outstanding technical skill with the provision of an abundance of technical training to the next generation of artisans offers us an example of one important mechanism that accelerated the process of innovation that we have described above: the concentration of training in the workshops and firms of highly skilled masters. To understand how this concentration of training in the hands of more skilled and productive artisans might affect innovation, consider the implications of three possible ways in which apprenticeship might affect the supply of skill in the next generation of workers.

First, if apprentices are evenly distributed across all workshops, then productivity will stay the same between generations. The capacities that each apprentice acquires will simply echo those of their master: skill levels will be replicated. Second, if most apprentices are learning with masters who are primarily interested in exploiting them as unskilled or semi-skilled labour, then the average skill level, and so the productivity, of the next generation of artisans will be relatively low. Finally, if apprentices mainly train with the most productive masters, then we might expect the average productivity of the next generation to increase as they pick up the best techniques and learn about the most profitable products and business strategies. This last «high-skill biased» distribution of apprenticeship training offers a method by which productivity grows incrementally and innovations are diffused.

Each of these ideal types is distinguished from the others by two factors that determine how effective apprenticeship is as a training system: first, the productivity of each master involved in supplying training; and second, the degree to which they tie up their apprentices in semi-skilled or unskilled tasks, rather than advancing them in their occupation by moving them through different aspects of the trade. For high-skill biased training to be in place, masters need to be both skilful and not exploitative.

European history offers some evidence for the existence of all three modes of training. The first clearly echoes the idea of a standard artisan household with its complement of servants and apprentices that can be found in work on the European marriage pattern and, perhaps, the impact of rationing by guilds and cities which sometimes imposed quotas on the numbers of youths each master could take. The second existed in the sweat shops of nineteenth-century cities, and in some examples of pauper apprenticeship. The third fits well with accounts of early-modern parents investing considerable energy in identifying a suitable master for their child (eg: Ben-Amos 1994).

What we lack, however, is evidence for which of these modes of training was dominant within key locations for training. However, there are several clear predictions that we can use to identify which model is operating.

The first is that if the first of these modes of training – replication of skill through an even distribution of apprentices – is dominant then apprenticeship should be widely spread without concentrations of youths with any individual masters. The presence of clustering among apprentices is an indication that either low-skill or high-skill biased training (or perhaps both) may exist.

The second prediction is that if training is high-skill biased the skill of masters should correlate with the number of apprentices they train. We would expect the best masters to train the most apprentices if this model was dominant. Ability and achievement should be associated with concentrations of apprentices.

The third prediction is that in a high-skill biased situation the price of training should be higher where apprenticeships are being obtained in workshops that have an established cluster of training. Conversely, if concentration is driven by sweated labour and training is low-skill biased, then training in larger workshops should be cheaper.

Testing the applicability of these models of skill production requires us to look at the distribution of training and apprenticeship. In the rest of the paper, we approach this in three steps. First, we examine evidence for the concentration of training, engaging with our first prediction. The British workforce had a reputation for being exceptionally well-trained and we use evidence from England to test this idea (Mokyr 2009, 107-09). Then, we examine evidence for the association between skill and training in London and the Netherlands. Finally, we provide some evidence on the link between price and concentration of training.

3.1 The clustering of training

Was apprenticeship widely spread or was training concentrated? It is much easier to ask the question who trained apprentices than it is to answer it. In order to examine what we might think of as the training careers of masters, we have to first link together disparate individual records of apprentice contracts to a single master. To do this on any scale means addressing a series of problems, mostly centred on the potential for multiple masters to share the same or similar names, and for this reason few studies have considered this.

In this section, we focus on apprenticeship in four English cities of different types from the late sixteenth to the late eighteenth centuries: London was the centre of English training; Bristol was an expanding second-tier port; Gloucester was a substantial third-tier city; and Boston, was a small country town. For each, we reconstructed the training careers for large samples of masters using robust nominal linkage methods. We also created samples of guild members or urban citizens who did *not* appear in these registers taking apprentices. This group of individuals all had the ability to take apprentices, at least in contemporary legal and civic theory, but for some reason they did not.

Using this dataset, we can identify the main characteristics of the distribution of training. First, most freemen or urban citizens *never* bound any apprentices: only 43 per cent of guild freemen in London bound an apprentice in the forty years after they entered their guild. In Boston, Gloucester and Bristol, just 20 to 25 per cent of burgesses and freemen in these towns took apprentices. For these provincial cities, the share may be under-estimated because increasing numbers of citizens lived outside their towns from the early eighteenth century. Even allowing for that, only a minority of freemen or citizens can have taken apprentices. Masters who did train apprentices usually only bound a few over their careers. Nearly two-thirds of masters recruited between one and three apprentices.

Training large numbers of apprentices was very rare: just a tiny fraction of masters – between four and eleven per cent took six or more. In London and Bristol, only one percent of freemen took twenty or more. The norm among English urban masters was to have only a limited number of apprentices.

Yet, the majority of apprentices were trained by the minority of freemen who did take apprentices in larger numbers. In London and Gloucester, over half of all apprentices were trained by the 20 per cent of masters who took more than five apprentices. More than a quarter were trained by the seven percent of masters who took ten or more. In Bristol, 42 per cent of apprentices were taken by the 12 per cent of masters who took more than five over their career. In Boston, 62 per cent of apprentices trained by the 33 per cent of masters with more than five apprentices. Large masters had a disproportionate effect on the supply of labour and the formation of the next generation of the workforce.

The majority of apprentices were trained by one of the minority of masters who did take apprentices repeatedly: concentration of training existed. We can safely reject the idea that in England apprenticeship was evenly distributed across workshops in a way that would simply reproduce the skill level of the workforce.

3.2 Training with skilled masters

What type of master was taking apprentices? As we have seen, the majority of youths were crowding into a minority of businesses. These were certainly the most active firms in terms of training, but were they also the best and most skilful masters as predicted in our model of high-skill biased training? In this section, we consider indicators about the quality of masters who trained most youths.

Skill is perhaps the hardest of indicators to isolate historically. For most trades, the products have long since disappeared and their consumers left no record of their opinions. However, a handful of occupations – clockmakers, furniture makers, apothecaries, merchants and artists – allow us to observe the training practices of those who were working at the pinnacle of their profession based on surviving evidence of skill judged by contemporaries and later experts. We apply our method to evidence from England and the Netherlands.

3.2.1 England

Because clockmaking has been widely studied, we can identify thirteen individuals who were among the most important innovators in clock and watchmaking in early modern England. All but one trained apprentices, with the average (mean) being nine apprentices and the median six per master.[3] Tompion's 23 apprentices was the largest cluster, but George Graham – his partner late in his career – indentured 16 and Daniel Quare bound 14. Like Tompion, these were the leaders in their field. Graham made several improvements to the pendulum clock and invented several astronomical instruments, as well as producing the mural quadrant at Greenwich Observatory for Edmond Halley (Britten 1986; Turner 2008, 272-73, n. 25). Quare invented repeating watches and supplied clocks and watches to James II and William III (*ODNB*, s.v. 'Quare, Daniel'; Britten 1986). Their workshops were large, but they were also hubs of innovation: Graham had learned from Tompion; his own apprentices included Thomas Mudge, who later invented the lever escapement that is still used today in almost all mechanical watches (Britten 1986).

The leading craftsmen in the second craft, furniture making and wood carving, were distinguished by supplying the royal court and nobility. The eighteen elite furniture makers and upholsterers we identify in this way were all large suppliers of training: their mean number of apprentices was ten and the median was six.[4] They include William Cleare, who worked as a carver on the triumphal arch for Charles II's coronation, Badminton House, the Sheldonian Theatre and the Divinity School at Oxford university, and William Emmett, who was sculptor to the crown and worked on Whitehall Palace, Hampton Court, Kensington Palace and Temple Church; some of his carving at Temple Church in London still survives (Crook 1965). Cleare bound nine apprentices, Emmett took five. The scale of their work may well

[3] The thirteen were drawn from Britten 1986; Turner 2008 and Landes 1983. They were John Arnold, Josiah Aspinall, William Clement, John Ellicott, Ahaseureus Fromantel, John Fromantel, Goerge Graham, Joseph Knibb, Thomas Mudge, Daniel Quare, Thomas Tompion, Samuel Watson, Joseph Williamson, Henry Wynne.

[4] The sample of manufacturers used here contains 56 individuals selected from the *British and Irish Furniture Makers Online* dataset (https://bifmo.history.ac.uk/) on the criteria that they were active from 1650 to 1700 and are known to have supplied the crown, an aristocratic household, or produced distinguished work. They were linked to London guild records, primarily the Joiners. The Joiners company apprenticeship records begin in 1641, however their freedom records appear to be incomplete and we are unable to safely identify masters who did not train among the larger sample of distinguished makers.

have gave them more need for additional workers, but that work included some of the most distinguished projects of the period.

The elite of the third craft, goldsmiths and silversmiths, can be identified because they produced pieces that survive in collections today. Thanks to the painstaking work of David Mitchell and others, we can identify silversmiths from makers marks stamped into the objects they made – a treasure trove of flagons, tankards, salvers, candlesticks and other plate - and then reconstruct their training from the guilds' records.[5] We focus on 113 individuals whose work is preserved in museums, described in works of connoisseurship, and sold at auctions.[6] Three quarters of these silversmiths are known to have taken apprentices, and they bound an average of five apprentices. Those individuals for whom the most objects survive also trained more apprentices. Those with one surviving piece trained an average of 3 apprentices (median 2); those with two to four objects in collections bound 5 (median 4); those with five or more bound 7. The most prolific producer by this measure – Edward Gladwin whose mark survives on 17 different objects – indentured eight apprentices.

High levels of skill were associated with high volumes of training in London, whether in crafts like silversmithing, furniture making, or clockmaking. Taking apprentices was the norm amongst them: all but one elite clockmaker, and four-fifths of silversmiths bound apprentices, compared to just two-fifths of London's freemen. The average number of apprentices they trained was high. The median elite goldsmith took 5 apprentices, the median elite clockmaker took 6, the median elite furniture maker took 10. The leading figures in each of these crafts recruited heavily and trained prolifically: they were among the group who trained a majority of the next generation. These innovative craftsmen and entrepreneurial traders did not shut their doors to outsiders to keep their secrets to themselves. Instead, the most skilful artisans also trained large numbers.

3.2.2 The Dutch Republic

No equivalent information, let alone across a variety of trades, is available for the Dutch Republic. However, data from the seventeenth-century painting industry seem to support the trend we observed for England: successful masters were training a disproportionate number of pupils.

One obvious example is Rembrandt, who was already a celebrated and internationally famous painter during his lifetime. In the winter of 1667, Cosimo III de' Medici – Grand Duke of Tuscany and the scion of an illustrious family of art connoisseurs – visited Rembrandt's studio to see with his own eyes the «pittore famoso» and his work (Bikker 2019: 181). During a career that lasted from 1625 to his death in 1669, Rembrandt probably taught 18-20 young painters (Broos 1983). One of his first pupils, Gerard (or Gerrit) Dou, came to Rembrandt at the age of fifteen and with only a knowledge of drawing. Rembrandt had to teach him how to

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[5] *Goldsmiths' Database for the 17th Century* (database, Goldsmiths' Company, London); Mitchell, 2017.

[6] This is a sub-sample of those Mitchell identified based on taking their freedom between 1600 and 1670, so allowing their training careers to be observed in the guild's records. The linkage between marks and makers is not certain, but based on expert judgement.

paint, but also to prepare the canvas, make paints, and so on. Later in life, Rembrandt seems to have focussed on apprentices who had already acquired the basic skills. Govert Flinck was 21 years old when he joined Rembrandt's studio and had already trained for three years under a lesser master in Leeuwarden, a town quite removed from the Dutch Republic's cultural heartland. Ferdinand Bol was twenty years old when he came to Rembrandt, after initial training in Dordrecht (Middelkoop 2017; see also Bruyn 1991). Rembrandt would collaborate with his 'post-docs', but also asked them to copy his own work. Bol, and Flinck in particular, both worked in a style that displayed similarities with Rembrandt's, to the point that it has proved challenging to identify the originals and the workshop copies made by the apprentices. Rembrandt charged for the privilege of working alongside him, but also claimed the proceeds of his pupils' work.

Amsterdam was the most important centre for the painting industry in seventeenth-century Holland, and it was with good reason that Rembrandt moved there in 1631. However, next to Amsterdam there were a handful of secondary centres with substantial numbers of painters (Rasterhoff 2017). We have evidence about apprentices and their masters for two of them. In Haarlem we have evidence for the first half of the century about 36 masters training 87 apprentices whose own work has been documented. In other words, these were pupils who applied their skills in the painting trade.[7] The average number of such pupils per master was therefore 2.3. Of those 36, seventeen or almost half, tutored only one or two such apprentices. Among these was Judith Leyster, one of the very few female master painters during the Dutch Golden Age. She had one apprentice. Leyster stopped working as an independent master, however, after she married her colleague Jan Miense Molenaer and the pair moved to Amsterdam in 1636, just a few years after Rembrandt had done the same (Welu and Biesboer 1993). A handful of Haarlem painters from the period taught six, seven, and in one case even thirteen future painters, i.e. more than twice and up to almost six times the average number.

By far the most popular among these teachers was the most famous Haarlem painter of all time, Frans Hals. However, Adriaen van Ostade (7), Salomon de Bray (6), Karel van Mander (6), and Cornelis van Haerlem (6) also produced works that are nowadays in the collections of the most famous art museums in Europe, such as Louvre in Paris (all five), Hermitage in St. Petersburg (Hals, Van Ostade, De Bray, Van Mander), or the National Gallery in London (Hals, Van Ostade and Van Haerlem). Interestingly, Van Mander wrote a substantial book about painting in the Low Countries, inspired by Vasari's *Lives of the Artists*. In his book, Van Mander incorporated a substantial chapter on how to become a master painter.

It is a fact that some nowadays famous Haarlem masters taught few apprentices. This applies most obviously to Pieter Saenredam, whose church interiors are in the collections of the Louvre and National Gallery and were already collector's items in the seventeenth century. So we cannot claim that famous masters were always training many pupils. In Haarlem, however, fourteen per cent of training masters taught 44 per cent of pupils who are known to have been active artists themselves.

[7] Numbers calculated on the basis of Goosens 2001, 474-75 (appendix 4b).

In Utrecht, a school of painting emerged in the early 1600s that was heavily influenced by Italian examples, and one in particular: Caravaggio. These Utrecht painters were later labeled «Utrecht Caravaggisti» (Spicer and Orr 1997, and Ebert and Helmus 2018). In the financial administration of the local Guild of St. Luke, 73 pupils have been identified between 1611 and 1639 who were interested in learning the art of painting.[8] Another 34 were merely interested in drawing and they will be disregarded here. The apprentice-painters were tutored by eleven masters, but according to a by now familiar pattern, eight of them taught only one or two apprentices. On the other hand, Paulus Moreelse and Abraham Bloemaert had 28 and 13 pupils respectively. Together they taught more than half (56 per cent) of those 73 apprentices. Neither Bloemaert nor Moreelse was actually a Caravaggist. Bloemaert was famous for his religious work (he was a Catholic), Moreelse was primarily a portrait painter. Neither of them could match the originality of Frans Hals, but both are represented in the collections of the Louvre and Hermitage, Bloemaert also in the National Gallery, demonstrating their lasting international reputation. Interestingly, the same two men were founding members of the Utrecht Guild of St. Luke and served many turns on the board of the guild. Like Saenredam in Haarlem, Utrecht had another well-known painter who taught a mere three apprentices: Joachim Wtewael (or Uytewael; represented in all three museums). Surprisingly, none of the Caravaggisti features in the list of teaching masters.

The individual example of Rembrandt, who trained numerous pupils, including several who themselves became famous, is confirmed in both Utrecht and Haarlem: the most famous masters attracted a large share of the apprentices trained in their towns during the seventeenth century.

4. Conclusion

The literature on modern Vocational Education and Training (VET) shows how in Europe today, various systems to prepare youngsters for skilled jobs exist next to each other – and have done so for the last hundred years. The implication of this lack of convergence suggests that there is no obvious best-practice solution for all countries to adopt, because this type of education is context sensitive; various industries, but also national traditions of education, determine the effectiveness of skills education (Thelen 2004; Billett 2011). One element that might apply in all systems, it has been suggested, is that high-end skills training is most effective in de-centralised environments and that these are also more innovative (Finegold 2006). This literature is, however, inconclusive about what other elements might determine the outcome of VET.

Our analysis suggests that the focus on institutions shared by modern and historical analyses of apprenticeship may have missed an important element of the contribution it provided. In this paper, we have set out a mechanism by which apprenticeship contributed to incremental economic development by (i) positively selecting the set of skills that were reproduced among the next generation of workers and (ii) disseminating best practice across the economy.

[8] The data were collected and published by Bok 1990: 65-66.

Training apprentices was a game for the successful in early modern English towns and cities. Apprentices were clustered in the businesses of a minority of masters who took relatively large numbers compared to most of their peers. Not all apprentices experienced this: many masters did take a solitary youth, if they trained at all. Not all apprenticeship contracts would be completed, even in the most advanced workshops. But the masters who recruited the most apprentices and who trained the majority of the next generation were the most skilled and most successful; they were also the leaders of their guilds and the wealthiest members of their communities.

While they took the majority of youths, they were not feeding them into sweated workshops in which apprentices were crowded side by side on a proto-production line. Instead, even those masters with the largest businesses mostly had only a few apprentices concurrently. Apprentices were spread out over a master's career, and often staggered in ways that must have allowed the newcomer to learn from an advanced apprentice on the verge of leaving. That youths were able to receive exposure to the full operations of the firm and training in its activities and areas of expertise rather than simply suffer exploitation in some shallow niche of semi-skilled production seems a reasonable inference for these businesses in early modern English towns and cities.

The associations we can show are strong between different indicators of success and training, but in the final analysis they do not inform us directly about the quality of training and exposure or the creative and productive potential of their workshop the apprentice received. Nonetheless, while we currently lack the evidence that would allow us directly to show with greater precision a virtuous cycle of diffusion with skill, knowledge and technique spreading out from the leading lights of each occupation, it seems likely that this was one important consequence of the distribution of apprenticeship apparent in England's towns and cities. Families chased skill; and skill drove development. By focusing young workers experience of labour and learning in the workshops and businesses of the wealthiest and most substantial masters, apprenticeship spread the best ideas across the economy of England.

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Innovazioni nella tecnologia, nella produzione e nel commercio

Innovations in technology, production, and commerce

Fabrizio Antonio Ansani

Le conseguenze economiche dell'innovazione bellica. La produzione di «artiglierie alla francese» a Firenze tra Quattro e Cinquecento

1. La soluzione tecnologica ad un problema militare

Nel 1495, le prestazioni delle artiglierie di Carlo VIII avevano fortemente impressionato ambasciatori, condottieri e principi italiani. Le armi straniere, ritenute da alcuni commentatori «più tosto diabolici che umani instrumenti» (Guicciardini 1981, 162), avevano stupito soprattutto per la loro inedita efficacia (de Commynes, 1528, 8r), potendo radere al suolo intere fortezze «in poche ore o giorni» (Desjardins, Canestrini 1859, 311). Molti cronisti ricordavano il terrore indotto dalla «più bella artigliaria che fusse vista mai alli nostri dì» (Tedallini 1904, 291), ed altri osservatori ancora notavano le caratteristiche innovative di questi armamenti «de altra foggia e diversa da quella de Italia», tutti «de uno pezzo» e «lunghissimi», di bronzo, «e de tale cera che passava dieci piede di bon muro. Ma non traevano se non pallotte de ferro. Et portava e conduceva questa artigliaria sopra de doi rote grande, maggiure o minore, secondo el peso, le quale carre tiravano li cavalli» (Matarazzo 1851, 63-64). Agli occhi increduli dei testimoni, questi mezzi venivano mossi con così tanta «prestezza» e maestria che «ne' luoghi piani pareggiavano» la marcia dell'esercito, procedendo speditamente anche sulle malridotte infrastrutture viarie medievali (Giovio 1555, 59v).

L'impressionante mobilità delle artiglierie transalpine contrastava nettamente con l'esasperante lentezza delle vecchie bombarde, il cui impiego era stato spesso condizionato dall'improvvisazione dei preparativi logistici e dalla relativa «grande spesa»: per le loro eccessive dimensioni, le «sconcie et intrattabili» armi richiedevano infatti l'impiego di centinaia di guastatori e di decine di buoi per essere posizionate, mentre numerosi carri dovevano essere requisiti per trasportare i pesanti proiettili di pietra e le strutture lignee che sostenevano il macchinario (Biringuccio 1558, 79rv). Più «agili a maneggiare et a condurre», i moderni cannoni sembravano costituire la perfetta risposta ai problemi della tattica ossidionale rinascimentale, una soluzione così convincente da essere presto adottata da tutti i governi della Penisola. Entro la fine del 1499, pezzi «alla francese» venivano fabbricati a Napoli, a Roma, a Venezia, a Siena, a Lucca, a Pisa (Ansani 2019, 369-78), anche grazie alla capacità di quei maestri che, negli anni precedenti, avevano ampiamente sperimentato delle significative ibridazioni tra i «moderni» modelli transalpini e le artiglierie leggere italiane (Ansani 2021b, 271-95). In quel di Ferrara, l'apprezzamento per

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Referee List (DOI 10.36253/fup_referee_list)
FUP Best Practice in Scholarly Publishing (DOI 10.36253/fup_best_practice)

Fabrizio Antonio Ansani, *Le conseguenze economiche dell'innovazione bellica. La produzione di «artiglierie alla francese» a Firenze tra Quattro e Cinquecento*, © Author(s), CC BY 4.0, DOI 10.36253/979-12-215-0092-9.13, in Giampiero Nigro (edited by), *L'economia della conoscenza: innovazione, produttività e crescita economica nei secoli XIII-XVIII / The knowledge economy: innovation, productivity and economic growth, 13th to 18th century*, pp. 195-208, 2023, published by Firenze University Press, ISBN 979-12-215-0092-9, DOI 10.36253/979-12-215-0092-9

l'*artillerie royale* aveva addirittura portato all'avvio di impianti riservati alla produzione di armi, carri e pallottole (Calegari 2005, 63-70), un esempio presto seguito dal duca di Milano (Motta 1914, 223).

2. I costi dell'innovazione tattica, i problemi dell'industria bellica

Avendone apprezzato i «grandi effecti» nelle parole dei loro ambasciatori,[1] anche gli officiali della Repubblica di Firenze avevano scelto di adottare gli armamenti degli invasori «oltramontani» e di incentivare lo sviluppo delle manifatture belliche. Già nel febbraio del 1495, la magistratura militare dei Dieci di Balìa aveva contrattato con un mercante pistoiese dei «modelli bellissimi da fare artigliarie di più ragioni, che dice haverli havuti da certi franciosi»,[2] nel tentativo di riprodurre quegli «ingegni perfettissimi». Per la stessa ragione, due fonditori erano stati incaricati di «pigliare le misure e disegnare pezzo per pezzo» tutte le artiglierie del «cristianissimo re» allora depositate in Romagna, in modo da poterle fabbricare «per i bisogni del nostro Comune, perché le faccino più a proposito et commode al servirsene».[3] L'imitazione dei manufatti doveva rivelarsi, ancora una volta, un valido mezzo di trasmissione del sapere (Hilaire-Perez, Verna 2006, 538; 544): nel marzo di quello stesso anno, un primo «cortaldo alla francese» veniva inviato all'esercito gigliato, allora impegnato nella repressione della ribellione pisana.[4]

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[1] Archivio di Stato di Firenze (ASF), *Dieci di balìa*, *Missive*, 32, c. 79rv. Nella lettera, i magistrati commentavano la scelta di iniziare a produrre cannoni «perché ci è affermato che queste artiglierie franzesi sono molte buone et fanno grandi effecti». Aspettavano comunque di averne prova: «sapreteci dire che effecto le fanno, perché se fussino come c'è detto, et come noi crediamo, ne faremo fare qualcuna qui. Quando non facessino buoni effecti, leveremo mano et lasseremo indietro le artillerie franzesi et torneremo alle taliane».

[2] ASF, *Dieci di balìa*, *Responsive*, 38, c. 244r.

[3] ASF, *Dieci di balìa*, *Missive*, 31, c. 81r. L'artigiano era Francesco Telli, il principale «maestro di artiglierie» della Repubblica Fiorentina. Con lo scoppio delle Guerre d'Italia, a lui era stata assegnata la gestione delle fonderie statali, forse per una sua diretta conoscenza della tecnologia transalpina: ASF, *Dieci di balìa*, *Munizioni*, 5, c. 15v. Quanto all'imitazione degli oggetti, avvenuta senza alcun tipo di resistenza da parte delle autorità militari francesi, l'intervento di Maryanne Kowaleski durante la LIII Settimana di Studi ha permesso di chiarire l'assenza di qualsiasi 'segreto militare' attorno alla produzione delle armi da fuoco, almeno per il quindicesimo secolo. Pur trattandosi di un sapere fondamentale per la sicurezza, il «getto» delle artiglierie costituiva infatti una tecnologia aperta, disponibile e replicabile da qualsiasi stato, purché inserito nel tessuto delle «leghe» generali o particolari. Contrariamente a quanto avveniva per altre manifatture armiere, le autorità italiane non ponevano inoltre restrizioni sul trasferimento dei loro fonditori, non dovendo proteggere alcun tipo di primato economico. Neppure le corporazioni riuscivano a imporre vincoli alla circolazione della manodopera, non afferendo i pratici ad alcuna specifica «arte».

[4] ASF, *Dieci di balìa*, *Munizioni*, 5, c. 38r. Anche a Firenze, la rapida adozione dei nuovi cannoni era stata resa possibile dai precedenti incroci tra la tradizione bellica italiana e le moderne tecnologie transalpine: la realizzazione di alcune «charrette pe' passavolanti» nel gennaio del 1485 è ad esempio ricordata in ASF, *Dieci di balìa*, *Responsive*, 30, cc. 146r, 174v, mentre in ASF, *Otto di pratica*, *Munizioni*, 1, c. 9v viene attestata la fabbricazione di due «chortali» gemelli nel luglio 1489. Come correttamente sottolineato in sede di discussione da Patrick Wallis, dunque, la rapida, impressionante assimilazione dei cannoni francesi coincideva in realtà con l'ulteriore sviluppo di soluzioni tecnologiche già ampiamente adottate nel contesto italiano, introdotte durante la feconda stagione di scambi militari, politici e diplomatici con la Borgogna di Carlo il Temerario.

Le alterne vicende di questo estenuante conflitto avrebbero presto portato lo stato fiorentino a dotarsi di un numero crescente di cannoni di bronzo (Graf. 1) e di una sostanziosa riserva delle materie prime necessarie a produrli (Graf. 2). Richiesta insistentemente dal capitano generale per il lancio di una vittoriosa, rapida controffensiva,[5] la realizzazione di trentadue bocche da fuoco aveva ad esempio comportato la fusione di sedici tonnellate di lega metallica nella sola estate del 1498,[6] uno sforzo reso possibile dalle ingenti quantità di rame e di stagno rivendute dagli imprenditori locali e dall'ordinato riciclo di materiali di scarto e di pezzi irrimediabilmente danneggiati. Vertiginoso e improvviso, l'aumento della domanda aveva inoltre spinto i Dieci di Balìa a costruire nuove fonderie pubbliche nella fortezza di Volterra e nel castello di Firenzuola, entrambe affidate ad artigiani direttamente stipendiati dalle autorità.[7] Anche i due «fornelli del Comune» esistenti a Firenze erano stati rinnovati e ampliati,[8] e sempre nella capitale erano state coinvolte nello sforzo bellico diverse altre botteghe private,[9] capaci di realizzare artiglierie «belle et buone» grazie alla significativa esperienza precedentemente accumulata in ambito artistico (Ansani 2017a, 756-78). Oltre a mobilitare i «maestri di getto» locali, il governo fiorentino avrebbe anche provato ad assumere numerosi artigiani stranieri per favorire l'acquisizione delle tecniche e la circolazione del sapere,[10] avvalendosi anche della mediazione degli oratori presenti nelle corti italiane ed europee (Desjardins, Canestrini 1859, 659).

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5 Si trattava di Paolo Vitelli, un condottiero con alle spalle una breve ma significativa militanza nell'esercito di Carlo VIII. In ASF, *Lettere varie*, 3, c. 256r, è possibile leggere una delle sue molteplici richieste di «cannoni, et polvere, et altre munitioni», per ottenere le quali sollecitava il suo cancelliere «de andare a palazo» spesso, «perché non mancho importano».

6 Sulla fabbricazione dei soli cannoni si veda ASF, *Dieci di balìa*, *Debitori e creditori*, 35, cc. 213v-214r, 223v-244r.

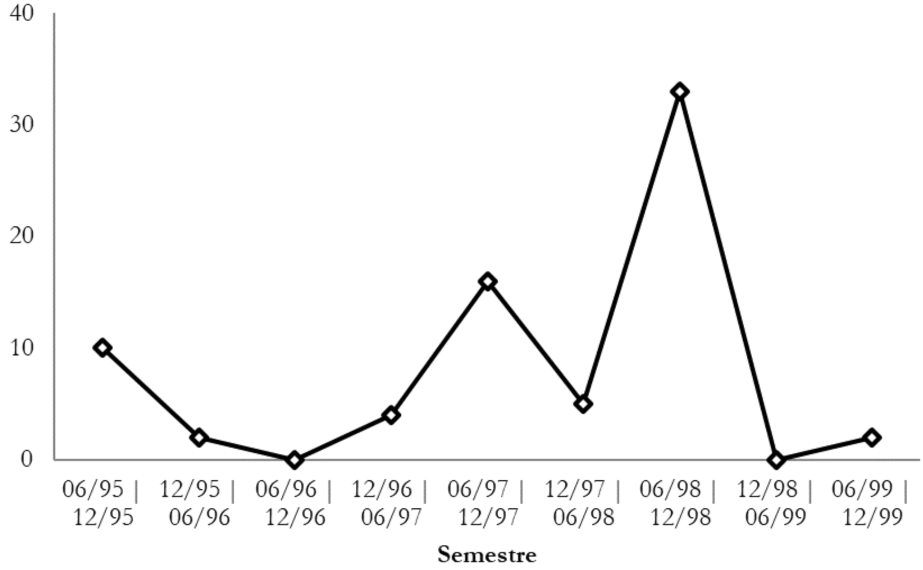
7 ASF, *Dieci di balìa*, *Munizioni*, 7, c. 50v.

8 In ASF, *Dieci di balìa*, *Deliberazioni, condotte e stanziamenti*, 31, c. 149r, sono annotate le spese per il rifacimento della «muraglia facta alla Sapientia per gittare artiglierie», attiva già ai tempi della Guerra di Ferrara. Un nuovo «fornello» era stato invece eretto nei pressi della «porta a San Francesco», sita accanto all'arsenale fiorentino della «Notomia»: ASF, *Dieci di balìa*, *Munizioni*, 7, c. 296v.

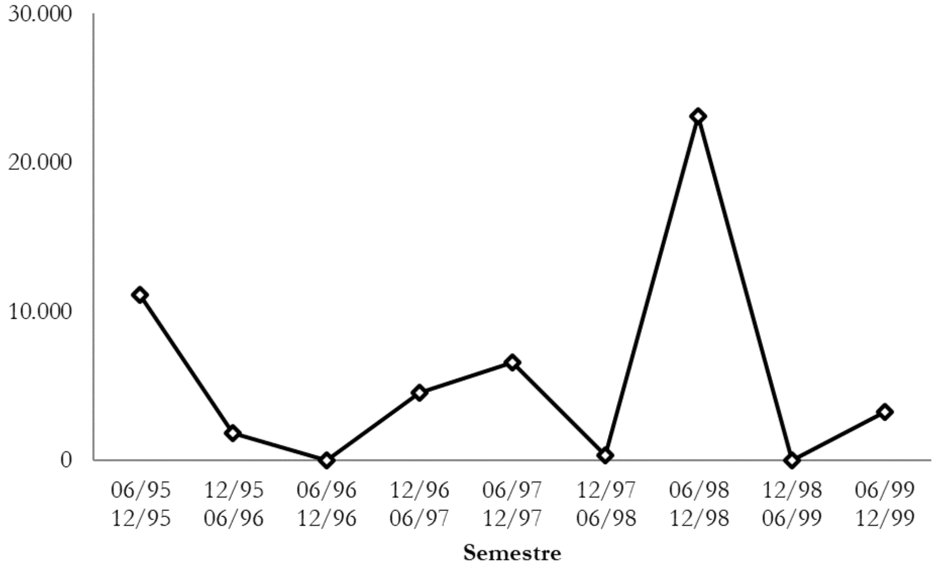
9 Tra i proprietari di questi opifici spiccano i nomi di Lorenzo «Cavaloro» e Ludovico «Orafo», i cui stessi soprannomi rimandano a lavori di gioielleria. Un altro fonditore assoldato ripetutamente dagli officiali sarebbe stato poi Bonaccorso Ghiberti, nipote del più famoso Lorenzo, autore di un conosciuto «zibaldone» di disegni tecnici. A questi artigiani si sarebbero aggiunti, nei periodi di maggiore necessità, anche «campanai» e maestri di zecca: ASF, *Dieci di balìa*, *Entrata e uscita*, 30, cc. 170v-174v.

10 Agli inizi del Cinquecento, nelle fonderie fiorentine avrebbero fatto la loro comparsa Giovannantonio da Novara e Bernardino da Milano, quest'ultimo destinato ad armare buona parte delle milizie machiavelliane: ASF, *Dieci di balìa*, *Munizioni*, 8, cc. 189r, 191v. Da notare è anche la collaborazione di questi maestri con diversi artisti fiorentini, tra cui lo scultore Giovan Francesco Rustici e il costruttore di organi Giovanni «Piffero», padre di Benvenuto Cellini.

Graf. 1. **Artiglierie «alla francese» fabbricate tra il giugno del 1495 e il dicembre del 1499, in unità**



Graf. 2. **Consumo di bronzo per la manifattura di artiglierie «alla francese», in chilogrammi**



L'assimilazione della tecnologia transalpina, tuttavia, non riguardava esclusivamente l'imitazione dell'arma da fuoco, quanto piuttosto la replica di un intero sistema produttivo volto a farla funzionare a dovere. Per la buona riuscita dei bombardamenti di saturazione adottati dai cannonieri francesi era ad esempio necessario disporre di migliaia di pallottole di «ferro colato» (Contamine 1964, 247-248), la cui produzione, nell'Italia del Quattrocento, era resa estremamente difficoltosa dalla mancanza di impianti siderurgici adeguati (Ansani 2021a, 288-289). Sebbene la presenza di un altoforno nel territorio fiorentino avesse facilitato il munizionamento dell'esercito per un breve periodo,[11] la prolungata assenza di investimenti – statali e imprenditoriali – nel settore metallurgico aveva presto determinato l'arresto della produzione (Borracelli 1996, 1218-1219). La questione era stata parzialmente risolta grazie all'attivazione dei circuiti mercantili, commissionando centinaia di pallottole in ghisa e di ferro battuto a Lucca,[12] ed acquistandone altrettante sulla piazza di Brescia, anche «contra a bando».[13] Ulteriori rifornimenti erano stati richiesti «o in compera, o in presto» a Mantova e a Ferrara, attraverso i consueti canali diplomatici.[14]

L'importazione di ingenti quantità di proiettili non eliminava però il problema strutturale: nel luglio del 1499, nell'imminenza dell'assedio di Pisa, la Signoria si era persino vista costretta a far fabbricare delle costosissime «palle di bronzo».[15] Nonostante le «difficultà» incontrate nella preparazione della singola campagna, il potenziamento degli opifici locali e il reclutamento della manodopera specializzata dovevano beneficiare enormemente, negli anni a venire, della spesa pubblica. L'interesse degli officiali aveva infatti permesso la riconversione di un altro «edificio del ferro» nell'area di Colle di Val d'Elsa, prontamente affidato alle esperte mae-

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[11] L'invio delle prime 128 pallottole è registrato in ASF, *Dieci di balìa*, *Munizioni*, 5, c. 37r. A produrre questi oggetti era stato Tommaso Marinai, uno dei principali imprenditori minerari fiorentini, proprietario dell'altoforno di Colle Val d'Elsa.

[12] Gli acquisti, effettuati dall'agente fiorentino Francesco Spina, sono riportati in ASF, *Dieci di balìa*, *Entrata e uscita*, 26, c. 320r. L'acquisto di 465 pallottole «di ferro di gietto» e di 888 tra «dadi e palle fatte a maglio» avrebbe comportato un esborso di 392 fiorini.

[13] ASF, *Dieci di balìa*, *Munizioni*, 7, c. 355rv. In questo «giornale in sul quale si terrà chonto di tutte l'artiglierie e munizioni» è annotato il contratto stipulato nel luglio del 1498 con un maestro bresciano, Agnolo di Filippo, e uno dei principali mercanti d'armi fiorentini, Baldo di Giovanni da Careggi. L'accordo riguardava specificamente la fornitura «di palle di ferro cholato di libre 50 in circha l'una, sechondo il modello, e di nostro a L. 13 per il cento di libre, portate al porto a Signa a ongni loro spesa salvo le gabelle del nostro territorio, i quali ci debbono dare in detto porto palle 200 per tutto dì V d'agosto prossimo a venire e palle 300 per tutto dì X detto, e volendone noi di poi insino alla somma di 1000 sia a nostro piacimento». I due intermediari sarebbero riusciti a procurare 379 pallottole, «pesorono libre 16.350, a L. 14 il cento montono L. 2289».

[14] ASF, *Signori*, *Missive prima cancelleria*, c. 134v.

[15] ASF, *Dieci di balìa*, *Entrata e uscita*, 30, cc. 170v-174r. Per la fusione di 689 pallottole di bronzo, la spesa totale, comprensiva dei salari dei maestri e dell'adeguamento dei «fornelli», era ammontata a 357 fiorini, ma non comprendeva che una parte del costo delle materie prime. Per la fusione dei proiettili erano infatti state consumate sette tonnellate di rame, tre tonnellate di ottone e una tonnellata di stagno, parte acquistate sul mercato cittadino e parte riciclate da materiali «chativi», che «disse esservi drento terra, mattoni e schiume».

stranze della montagna casentinese,[16] e un nuovo «fornello» era stato eretto in quel di Pistoia in seguito all'accordo stipulato tra i Dieci di Balìa e una compagnia di artigiani tedeschi, piemontesi e toscani interessati alla produzione di proiettili in ghisa e armi in ferro.[17] Agli inizi del Cinquecento, la produttività sarebbe stata decisamente, definitivamente migliorata. L'assunzione di maestri provenienti dall'area alpina avrebbe infatti consentito non solo un aumento sensibile nel rendimento degli altoforni,[18] ma anche la diffusione di questi nuovi macchinari nell'intera regione, a beneficio anche dell'industria civile del ferro.

Una delle maggiori difficoltà presentate dalla lavorazione della ghisa rimaneva in ogni caso l'approvvigionamento di minerale adatto alla fusione (Baraldi, Calegari 2001, 97-98), un problema peggiorato dall'ostinato, sbrigativo reimpiego di svariate tonnellate di «ferramenti vecchi».[19] La scarsa disponibilità di materie prime affliggeva inoltre la fabbricazione della polvere da sparo. L'essenziale, insostituibile componente del propellente – il salnitro – non veniva infatti estratto nell'area toscana,[20] costringendo la Repubblica a dipendere dalle relazioni coi paesi esportatori, non sempre allineati alla politica estera, marcatamente filofrancese, dei fiorentini (Ansani 2021b, 14-25). Con lo scoppio delle Guerre d'Italia, la carenza di nitrato doveva inoltre essere acuita da uno smodato consumo di esplosivi, la cui produzione era costantemente accresciuta dalla generale conflittualità di quegli anni e dalla crescita incontrollata dei parchi d'artiglieria della Penisola.[21] Agli officiali gigliati non restava pertanto che ammettere che «di nessuna cosa habbiamo carestia tanto quanto di questo» minerale, «né alcuna cosa ancora nelle nostre expeditioni imminenti è più necessaria».[22]

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16 ASF, *Signori e collegi*, *Condotte e stanziamenti*, 17, cc. 34v, 37v. Si trattava di «maestro Simone di Andrea da Romena», capace di realizzare, in «uno mese et octo giorni», e con l'assistenza di due «carbonai», 394 pallottole, ottenute dalla fusione di quattro tonnellate di metallo.

17 In ASF, *Dieci di balìa*, *Entrata e uscita*, 23, c. 542r, è possibile leggere della «composizione et merchato» siglata nel dicembre del 1498 con «maestro Giovanni di Piero di Chieri et Lancilotto di Voglino da Pistoia et maestro Antonio di Giovanni todescho per fare palle di ferro a proposito di loro signori a L. 13 di piccioli il cento in Pistoia, et schoppietti et archibusi a L. 20 il cento, et spingharde colle chode a L. 18 il cento a pruova et a loro spese, et dadi di ferro a L. 10 il cento posti in Firenze a ghabella di detti signori Dieci, et con condizione debbino essere serviti di presente di F. 50 larghi in oro». Nonostante le «difficultà» incontrate inizialmente, il contratto era stato rinnovato negli anni seguenti: ASF, *Dieci di balìa*, *Munizioni*, 9, c. 51r.

18 Si veda ad esempio la produzione registrata in ASF, *Dieci di balìa*, *Munizioni*, 10, cc. 76v-77r, relativa al primo semestre del 1508 e pari a circa un migliaio di pallottole al mese. Stando ai registri contabili, la manifattura sembrava concentrarsi allora nella stessa Firenze, nella vecchia fonderia della «Sapientia». A coordinare i lavori era Andrea di Jacopo da Colle Val d'Elsa, definito nelle fonti come «maestro di fare palle di ferro».

19 Nel luglio del 1499, tredici tonnellate di metallo usato erano state inviate dagli officiali di Arezzo, Firenze e Cortona per la fabbricazione dei proiettili: ASF, *Signori*, *Missiv*e seconda cancelleria, 21, c. 43v.

20 Cercate già in epoca laurenziana, le «miniere di salnitri» non sarebbero mai state trovate in territorio fiorentino. Di un tentativo è fatta menzione in ASF, *Carte Riccardi*, 816.

21 In ASF, *Signori*, *Responsive*, 12, c. 141rv, si fa esplicito riferimento alla «qualità de' presenti tempi».

22 ASF, *Dieci di balìa*, *Missive*, 60, c. 128r.

Terminato il monopolio del dissolto banco mediceo sui traffici di questo materiale strategico (Ansani 2021c, 10-15), i Dieci di Balìa avevano dovuto contare sull'iniziativa di diversi venditori, anche forestieri.[23] Le contrattazioni più importanti restavano comunque quelle condotte dagli ambasciatori gigliati a Roma, a Milano, a Siena, a Bologna, a Forlì:[24] in quanto figure pienamente investite dell'autorità statale, gli oratori potevano infatti contrastare, con la loro azione, l'aleatorietà dell'offerta di mercato, negoziando il prezzo della merce, le tempistiche del trasporto e la qualità del minerale sia con i fornitori privati sia con le «potentie» alleate. Tuttavia, negli arsenali della capitale non si sarebbe mai riuscita ad accumulare la quantità di minerale necessaria al prosieguo della lunga campagna pisana, neppure favorendo le importazioni con la totale abolizione dei dazi.[25] Per ovviare alla cronica scarsità della merce, i magistrati avevano infine provato ad impiantare alcune «nitriere» artificiali nell'area aretina e sulla frontiera romagnola, accordando licenze e privilegi agli artigiani provenienti dal vicino Stato della Chiesa per ottenere, almeno in una prima fase, dei risultati piuttosto scarni.[26]

Il commercio interno era stato incentivato anche per ottimizzare le forniture degli altri due ingredienti principali della polvere nera, cioè lo zolfo, facilmente reperibile nella regione vulcanica di Volterra,[27] e il carbone, ampiamente utilizzato nel distretto ceramico di Montelupo.[28] Una volta convogliate a Firenze, queste materie prime venivano immediatamente consegnate ai maestri per la fabbricazione dell'esplosivo – un bene ormai fondamentale per la guerra d'assedio, perché «senza non se fa niente», e «ad quello sta el vinciare et el perdare» (Nicasi 1915, 157). In seguito all'introduzione dei cannoni francesi, la domanda era cresciuta vorticosamente (Graf. 3): nelle prime settimane di impiego estensivo delle nuove artiglierie erano andate letteralmente in fumo trentasette tonnellate di polvere, moltiplicando

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[23] Tra i principali venditori si ricordano i fiorentini Antonio del Migliore, Giovanni Biliotti, Leonardo Strozzi e Piero Berti, il senese Giulio Spannochi, il lucchese Benedetto Buonvisi e il genovese David Lomellino. I loro nomi si leggono in ASF, *Dieci di balìa*, *Munizioni*, 7, cc. 272r, 274v, 362r, in ASF, *Dieci di balìa*, *Entrata e uscita*, 30, c. 180v, e in ASF, *Signori e collegi*, *Condotte e stanziamenti*, 17, cc. 31r, 74v, 270v.

[24] Su Roma, ad esempio, si veda ASF, *Dieci di balìa*, *Legazioni e commissarie*, 23, cc. 97r-98r. Il relativo contratto è registrato in ASF, *Dieci di balìa*, *Entrata e uscita*, 23, c. 351v.

[25] Un esempio in ASF, *Dieci di balìa*, *Missive*, 59, c. 119v. Il salnitro doveva essere lasciato «passare immune et sanza alcuno pagamento».

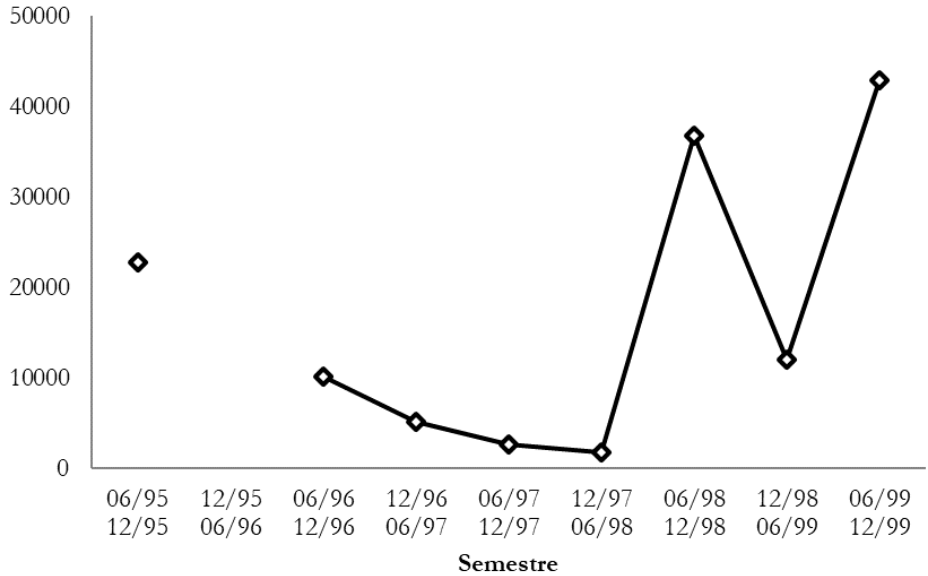
[26] Stando a quanto riportato in ASF, *Dieci di balìa*, *Debitori e creditor*i, 28, c. 40v, il primo stabilimento di questo genere sarebbe stato inaugurato in quel di Castrocaro nei primi mesi del 1496, su iniziativa di Antonio di Jacopo da Faenza. I contratti coi «maestri di fare salnitro ad Arezzo» risalirebbero invece al decennio successivo: ASF, *Dieci di balìa*, *Munizioni*, 9, c. 168v.

[27] ASF, *Dieci di balìa*, *Missive*, 60, c. 134r. La patente rilasciata al «vetturale» Giovanni di Benozzo imponeva a tutti i «doganieri, passaggieri et stradieri della iurisdictione fiorentina» di non riscuotere «gabella o datio di alcuna qualità» sullo zolfo diretto «in Firenze per conto del magistrato nostro».

[28] In ASF, *Dieci di balìa*, *Missive*, 59, c. 104r, veniva ad esempio accordata a Bonarrigo di Matteo d'Artimino una licenza per il taglio degli alberi necessari alla realizzazione di «carboni di salcio per far polvere da bombarda», in seguito alla stipulazione di una «convenzione» con i magistrati. Per «darne maggior quantità», l'artigiano «richiede di favore apresso qualunque nostro officiale» sul territorio. Il materiale vendut*o ai Dieci di balìa nel*l'estate del 1498 veniva inoltre esentato dal pagamento delle imposte: ASF, *Dieci di balìa*, *Munizioni*, 7, c. 426v.

di ventidue volte i consumi del semestre precedente.[29] Per le successive operazioni militari si sarebbero persino dovuti svuotare i depositi di decine di borghi, città e castelli, esaurendo completamente le riserve dello stato.[30]

Graf. 3. **Produzione di polvere da sparo, in chilogrammi**



Per fronteggiare la costante richiesta di propellente, il governo gigliato aveva in ogni caso disposto la costruzione di moderni opifici a Livorno e a Firenze, entrambi affidati ai «maestri di polvere» stipendiati dalla Repubblica.[31] Numerosi lavoratori non specializzati, tra cui un pittore, ma anche molti falegnami, erano stati invece assunti per gestire i lavori nel vecchio impianto meccanizzato della capitale,[32] un

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[29] Per la sola campagna del 1498 erano state consumate circa trentasette tonnellate di polvere, come si desume dai conti riportati in ASF, *Dieci di balìa*, *Debitori e creditori*, 35, cc. 180v, 242v, 251v, 286v. La spesa complessiva aveva sfiorato, per l'occasione, i duemilacinquecento fiorini, una cifra comprensiva dei salari dei maestri e del costo dei materiali.

[30] Le autorità dovevano infatti ammettere che, dopo la requisizione dell'esplosivo nelle principali cittadelle, «della polvere non ci è puncto»: ASF, *Signori*, *Missive seconda cancelleria*, 21, c. 88r.

[31] Sul finire del secolo, i migliori maestri a disposizione dei Dieci di balìa restavano Piero di Zanobi e Jacopo di Corso, spesso citati nelle fonti coi loro soprannomi di «Zucca» e di «Baia». La copia della loro «conducta pulveris» è presente in ASF, *Dieci di balia*, *Deliberazioni, condotte e stanziamenti*, 35, cc. 15v-16v.

[32] Dopo aver realizzato per anni carrette per le artiglierie e impugnature di archibugi, il «legnaiolo» Bartolomeo di Ventura Banchini era presto divenuto «nostro maestro d'affinare salnitri e fare polvere nella munizione dell'antiporto della porta a San Nicholò di Firenze». Il suo coinvolgimento nella manifattura dell'esplosivo doveva probabilmente essere motivato dalle impellenti necessità del conflitto contro i pisani. Il suo frenetico, indispensabile lavoro è ben rendicontato in ASF, *Dieci di balìa*, *Munizioni*, 7, cc. 446v-447r, 496v-497r.

compito che doveva perlopiù limitarsi alla corretta pesatura dei materiali e al controllo del regolare funzionamento delle apparecchiature (Ansani 2019b, 245-49). Nonostante il costo elevato della manodopera professionale e la lentezza della lavorazione manuale, in caso di estrema necessità venivano richiamati in servizio alcuni speziali cittadini, perlopiù membri di famiglie che da decenni si occupavano del confezionamento della miscela.[33]

3. Le artiglierie come oggetto economico

Per potersi avvalere della moderna tecnologia bellica, la Signoria aveva dunque bisogno della piena disponibilità di un significativo numero di artigiani, sia nella città capitale che nell'intero dominio. Ai produttori di polvere, pallottole e cannoni si affiancavano infatti i «maestri di carra», indispensabili alla realizzazione di robusti veicoli per le nuove artiglierie,[34] nonché gli scalpellini e i «mattonai» impiegati nella costruzione degli arsenali e nell'edificazione delle fornaci.[35] Un ruolo ovviamente indispensabile era poi quello dei «bombardieri» italiani, greci, tedeschi, portoghesi, francesi, variamente reclutati a seconda della necessità della guerra (Graf. 4). Guadagni piuttosto cospicui erano infine quelli realizzati dagli «scafaioli», dai «carradori» e dai mulattieri incaricati del trasporto degli armamenti dalle botteghe al campo di battaglia.[36] Per questi come per altri lavoratori, le trasformazioni tardomedievali dell'industria bellica dovevano insomma costituire una concreta opportunità di occupazione, di investimento o di profitto, oltre che una sostanziosa integrazione del normale salario (Caferro 2008, 198-200).

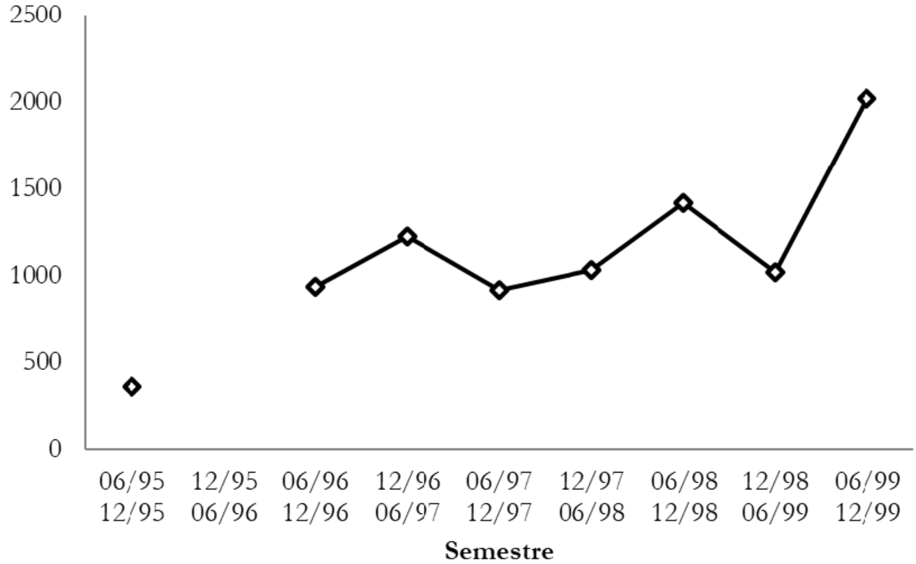
[33] ASF, *Dieci di balìa*, *Entrata e uscita*, 30, cc. 192v, 194r. Le famiglie in questione sono quelle dei Barducci e dei Formiconi, entrambe attive nel settore da più di cinquant'anni.

[34] Questi artigiani erano particolarmente lodati dai condottieri fiorentini, come si legge in ASF, *Lettere varie*, 3, c. 350r. La costruzione di queste «charrette alla franzese» era caratterizzata dall'impiego di assi ritorti e di ruote rinforzate, nonché dalla presenza di una «chassetta» per i proiettili. Tra principali fabbricanti i due fratelli Bifolchi, Lorenzo e Francesco, originari di Prato, menzionati più e più volte in ASF, *Dieci di balìa*, *Munizioni*, 7, cc. 360r, 367r.

[35] Conosciuto per i suoi lavori a Palazzo Strozzi e nel Salone dei Cinquecento, l'architetto Simone del Pollaiolo aveva contribuito anche alla costruzione dell'arsenale della «porta alla Giustizia», come si legge in ASF, *Dieci di balìa*, *Entrata e uscita*, 15, c. 255v. Lo stesso «scharpellino» realizzava inoltre proiettili «di sasso» per l'esercito fiorentino. Nell'agosto del 1498 gli veniva affidata la manifattura di pallottole «a S. 14 l'una delle grosse da libre 150 in su e S. 10 l'una da libre 50 in 100 l'una»: ASF, *Dieci di balìa*, *Munizioni*, 7, cc. 374v, 459v.

[36] Decisamente significativo, in tal senso, l'importo versato al «vetturale» Giovanni del Caccia e ai suoi quarantacinque compagni, superiore alle diecimila lire di piccioli e relativo ai lavori di quattro mesi: ASF, *Dieci di balìa*, *Deliberazioni, condotte e stanziamenti*, 33, cc. 234r-235v, 240-241v. Dalle stesse carte traspare l'importanza del trasporto fluviale, in genere affidato alla ditta dello «scafaiolo» Piero di Damiano, meglio conosciuto come «el Baldoria».

Graf. 4. **Paghe dei bombardieri, in fiorini d'oro**



La partecipazione attiva alle strategie governative, d'altronde, beneficiava gli artigiani anche in termini di mobilità sociale (Torres-Sanchez, Brandon, e 't Hart 2018, 7), avvicinandoli progressivamente ai centri del potere ma rendendoli allo stesso tempo esposti alla violenta competizione tra le varie consorterie fiorentine sorte dopo la caduta del regime mediceo.[37] Ma la fruttuosa collaborazione tra gli operatori economici e lo stato rinascimentale (Parrott 2012, 2-3) doveva soprattutto favorire i mercanti-banchieri appartenenti all'aristocrazia cittadina, premiati con esenzioni fiscali e posizioni amministrative non solo per i generosi prestiti, ma anche per le indispensabili, costose risorse materiali fornite agli officiali militari, come il salnitro e il rame, faticosamente reperite sui mercati europei e mediterranei.[38]

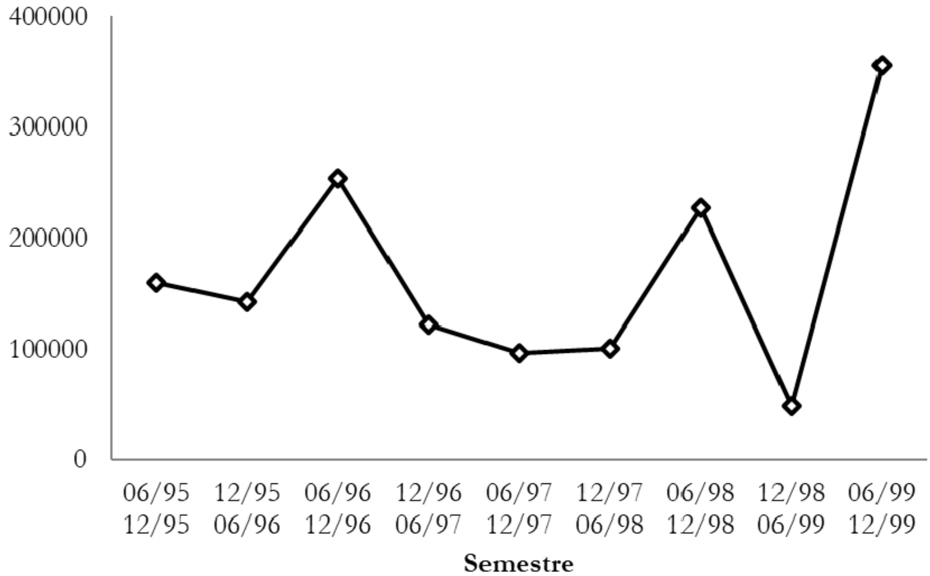
Con il rapido innalzamento della domanda e il relativo incremento nella produzione di «polvere et palle», la cooperazione tra governo e commercianti doveva par-

[37] Decisamente notevole il caso di Baldassarre di Giovanni, un fabbro arricchitosi grazie al sostegno garantito alla fazione savonaroliana ma immediatamente caduto in disgrazia dopo il rogo del frate. La disparità di trattamento è ben evidenziata dalla netta differenza tra le commissioni dei primi mesi del 1497 e quelle del tardo 1498. Col partito «piagnone» al potere, infatti, l'artigiano riusciva a vendere bombarde, spingarde e archibugi, ricevendo migliaia di lire anche in virtù di pagamenti in «soprameritо», lievitati grazie ad una lieve maggiorazione dei prezzi. Dopo il naufragio dell'oligarchia savonaroliana, nonostante la forte ripresa delle ostilità contro i pisani, gli affari si limitavano invece alle forniture di chiodi, pali e martelli, con una drastica diminuzione dei guadagni. In ASF, *Dieci di balìa*, *Munizioni*, 7, cc. 20v, 60r, 343r.

[38] Diversi componenti della famiglia Strozzi, ad esempio, fornivano rame, stagno e salnitro ai magistrati della guerra, come si legge in ASF, *Dieci di balìa*, *Entrata e uscita*, 30, cc. 169v, 180v. A questi prodotti si aggiungevano inoltre decine di migliaia di lance, per le quali si ritrovano sostanziosi acquisti in ASF, *Dieci di balìa*, *Munizioni*, 7, cc. 9r, 15v. Da notare come un altro membro della dinastia fosse divenuto, in quegli stessi anni, camerlengo dell'officio e commissario generale in campo: ASF, *Dieci di balìa*, *Missive*, 60, c. 97v.

ticolarmente interessare, più che in passato, la manifattura delle «munitioni», un'industria che da sola assorbiva più del dieci percento dei bilanci semestrali dei Dieci di Balìa (Graf. 5).[39] Sul finire del quindicesimo secolo, l'investimento statale sulla produzione di nuovi armamenti e sul reperimento di materie prime superava complessivamente i diecimila fiorini annui (Graf. 6),[40] una cifra ulteriormente accresciuta dal finanziamento indiretto degli acquisti effettuati dai condottieri al soldo della Repubblica.[41] La contabilità di guerra conferma però come questa spesa non si traducesse soltanto nel mero approvvigionamento dell'esercito, ma stimolasse semmai l'acquisizione di tecnologie innovative, la migrazione di manodopera specializzata, l'erezione di particolari impianti, la commercializzazione di svariati prodotti e il sostegno di importanti industrie, anche civili.

Graf. 5. **Spesa di guerra della Repubblica Fiorentina, in fiorini d'oro**

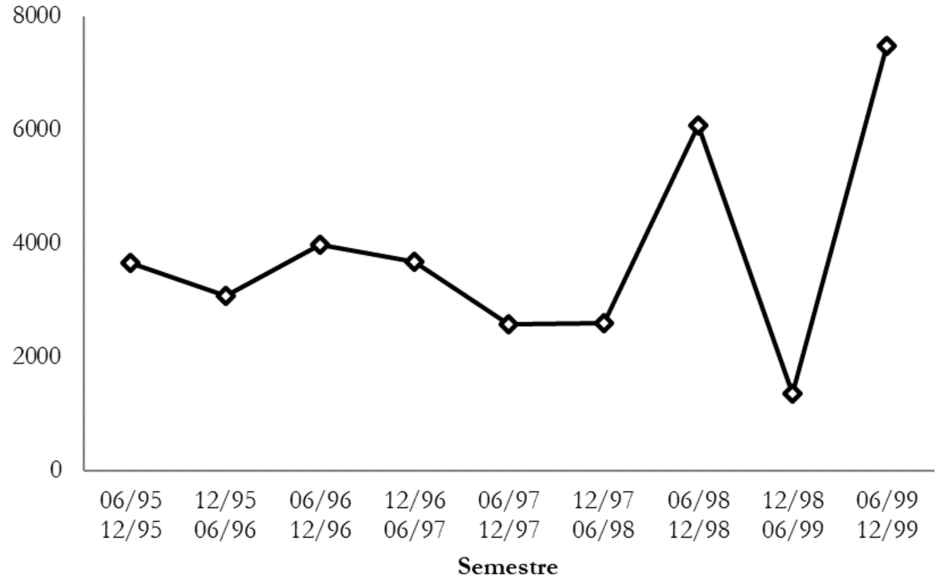


[39] ASF, *Dieci di balìa*, *Debitori e creditori*, 39, c. 292v. Il risultato si ottiene accorpando le voci «spese di munizione», «spese di vetture», «bombardieri» e «maestranze». Nel complesso, la spesa per gli armamenti e per gli artigiani si collocava soltanto dietro ai pagamenti dei salari per gli armigeri e i fanti.

[40] A tanto dovrebbe ammontare il cambio di «F. 3049 d'oro, F. 1633 S. 1 D. 6 di grossi, L. 19861 S. 11 D. 8 di piccioli» spesi tra l'estate del 1499 e la primavera del 1500, come attestato nel bilancio presente in ASF, *Dieci di balìa*, *Debitori e creditori*, 45, c. 329v. Per la sola preparazione del fallimentare assedio condotto da Paolo Vitelli l'esborso per le «munitioni» assommava a «F. 219 larghi in oro, F. 911 et D. 6 larghi di grossi et L. 13419 S. 4 D. 2 di piccioli», pagati dagli officiali in soli due mesi: ASF, *Signori e collegi*, *Condotte e stanziamenti*, 17, c. 33v.

[41] L'anticipo fornito sulla paga, la cosiddetta «prestanza», serviva solitamente per l'acquisto delle armi e delle cavalcature necessarie agli uomini d'arme. Se ne trova ancora traccia nelle condotte fiorentine dell'epoca, come quella siglata con Guidobaldo da Montefeltro nel maggio del 1495: ASF, *Dieci di balìa*, *Deliberazioni, condotte e stanziamenti*, 31, cc. 36r-42r.

Graf. 6. **Acquisti di armamenti, in fiorini d'oro**



Fin dagli esordi dell'età moderna, gli armamenti assumevano quindi una crescente rilevanza come oggetto economico, sebbene l'azione dello stato condizionasse fortemente la domanda, e l'offerta, di queste merci 'difficili' (Leydi 2007, 171-175). Il passaggio da un munizionamento gestito complessivamente dalle singole compagnie mercenarie ad una articolata industria policentrica coordinata interamente dalle autorità comportava infatti un più deciso intervento politico in questo settore strategico dell'economia pubblica, ed anche a Firenze la tendenza era evidentemente quella di monopolizzare la produzione e l'uso delle artiglierie attraverso l'istituzione di offici dediti esclusivamente alla pianificazione dell'aspetto logistico delle operazioni belliche e alla creazione di una migliore interfaccia tra il mondo produttivo e l'apparato militare.

A questa complessa struttura burocratica sarebbe spettata la gestione degli arsenali e la tenuta della contabilità, nonché, ovviamente, l'acquisto dei beni,[42] «perché sono molte chose, et questa è una di quelle che non bastono a provederle con danari».[43] Persino il tradizionale 'nerbo della guerra' non poteva allora sostituirsi

[42] A partire dal giugno del 1496 venivano nominati dai Dieci di balìa due sottoprovveditori, incaricati di coadiuvare i custodi degli arsenali e di «tenere conto di tutte le munitioni» insieme ai loro diretti superiori, cioè il provveditore, il camerlengo, e due membri della stessa magistratura. Parallelamente all'incremento della produzione si assisteva dunque alla moltiplicazione delle scritture relative alla produzione e al commercio di armamenti, come quelle contenute in ASF, *Dieci di balìa*, *Debitori e creditori*, 31, e ASF, *Dieci di balìa*, *Munizioni*, 6. In quello stesso periodo iniziava inoltre una «rasegnia» di «tutti e' luoghi dove saranno munizione e artiglierie», i cui esiti venivano presentati in ASF, *Dieci di balìa*, *Entrata e uscita*, 16.

[43] ASF, *Signori*, *Missive seconda cancelleria*, 21, c. 65v.

all'efficientamento della rete manifatturiera, al coinvolgimento degli attori commerciali e alla razionalizzazione dell'organizzazione militare: anche da un punto di vista economico, l'introduzione dell'artiglieria «alla francese» segnava insomma la fine della tradizionale strategia medievale dell'improvvisazione e della rapina, accelerando processi già iniziati con la creazione, alla metà del Quattrocento, dei primi «offici della monitione», in Italia e in Europa (Ansani 2017b, 154).

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Markus A. Denzel

Bookkeeping as a 'key technology' of pre-modern commerce. Its relevance for the economic development in Europe[*]

1. Introduction

Since the classic studies of Werner Sombart (1863-1941), Max Weber (1864-1920) and Joseph Schumpeter (1883-1950), the significance of the emergence of double-entry bookkeeping for the economic development of Europe has been discussed (e.g. Melis 1991, 281-85; Miller, Hopper and Laughlin 1991; Bryer 1993; 2000; Todeschini 2006), not least at the 22nd Settimana di Studi in Prato in 1990 (Cavaciocchi 1991). According to Sombart (1902), the emergence of double-entry bookkeeping ultimately reflected the high rationality of the Upper Italian-Tuscan merchant bankers. For Weber, bookkeeping expressed calculability and was part of what he called the «spirit of capitalism» (Weber 1921/22, 49-50). In recent decades, authoritative representatives of historical accounting research, above all Basil S. Yamey since the late 1940s, have opposed such an exaltation, even glorification of accounting. Yamey (1949, 110) interprets accounting as a contribution to the «'methodising' of business life» and in particular concludes that knowledge of total returns is not mandatory or useful for decision-making within an enterprise (Yamey 1964, 119). Only in the peculiar situation of stable prices and costs did information from double-entry bookkeeping actually provide a viable basis for a corresponding, improved basis for decision-making (Yamey 1964, 128-29). Yamey (1964, 133) sees the benefit and merit of double-entry bookkeeping «in its comprehensiveness and its possibilities for the orderly arrangement of data», then in the possibility of finding and correcting arithmetical errors in the account books (Yamey 1949, 110; 1964, 135). For other representatives of current relevant research, the reporting of profit or loss is not the original and especially not the most important intention of (double-entry) bookkeeping (e.g. Sangster 2016, 301-02; Carruthers and Espeland 1991, 54; Napier 2009; Chapman, Cooper and Miller 2009; Lang 2020, 27-43). As most merchants were so deeply informed about their transactions a profit-and-loss account in the modern sense did not seem necessary. Therefore, there was no accurate and regular, but at best a periodic review of capital and income (Yamey 1949, 110-11; 1964, 119; 124; 135). As a result, one can agree with Richard A. Goldthwaite, who also rejects the thesis of a «spirit of capitalism» or a rational striving for unlimited profit, when he concludes with a remarkable qualification: «double entry, at least in its early but highly

[*] Translation by Franziska Streng B.A., Leipzig. I thank my dear colleagues and friends Mechthild Isenmann (Leipzig) and Gerhard Fouquet (Kiel) for helpful comments.

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Referee List (DOI 10.36253/fup_referee_list)
FUP Best Practice in Scholarly Publishing (DOI 10.36253/fup_best_practice)

Markus Denzel, *Bookkeeping as a 'key technology' of pre-modern commerce. Its relevance for the eco-nomic development in Europe*, © Author(s), CC BY 4.0, DOI 10.36253/979-12-215-0092-9.14, in Giampiero Nigro (edited by), *L'economia della conoscenza: innovazione, produttività e crescita economica nei secoli XIII-XVIII / The knowledge economy: innovation, productivity and economic growth,13th to 18th century*, pp. 209-235, 2023, published by Firenze University Press, ISBN 979-12-215-0092-9, DOI 10.36253/979-12-215-0092-9

sophisticated manifestation, was not inherently an instrument of capitalism as we understand it today» (Goldthwaite 2015, 637).

In recent years, however, cultural-historical interpretations of double-entry bookkeeping have increasingly been promoted, underlining its function as a social and institutional practice (e.g. Miller 1994; Carnegie and Napier 1996). Three such approaches are mentioned by way of example: to begin with, according to Aho (2005), double-entry bookkeeping was a 'rhetorical' artifice used by the church and merchants to justify their common business practices and notably their profit-making in the fifteenth century, which would otherwise have been considered immoral or usurious. Next, a quantifying and technological interpretation of account books, originating in the Annales school, emphasises the possibility of communication on several levels through double-entry bookkeeping, whereby bookkeeping is understood as an independent agent and as a meso level between the microeconomic of businesses and the macroeconomic of, for example, markets or crown finances, linking the two. The products of accounting – the accounts books – appear as «products of data processing», even as "achievements of cognitive artefacts", whereas their actual economic intention seems to recede into the background (Norman 2013; Llewellyn and Milne 2007; Lemarchand and McWatters 2013; Lemarchand, McWatters and Pineau-Defois 2014). Finally, a more intellectual, even art-historical interpretation points out that the Venetian accounting system is defined by symmetry, proportion, mathematical balance, order and harmony, which characterises Renaissance art as a whole (Dean, Clarke and Capalbo 2016, 10; Bryer 2016).

Against the backdrop of these current discussions, however, the question of possible economic backgrounds to the emergence of double-entry bookkeeping remains unanswered or must be asked anew. Provocatively put: did double-entry bookkeeping serve primarily or even solely to formalise, abstract and simplify the accounts, for example to avoid the appearance of usury? Was it really only – or at least essentially – rational, organisational criteria and ideas of order that induced merchants to take on the immense effort in terms of working time and costs that the preparation of double-entry bookkeeping requires (cf. Carruthers and Espeland 1991, 36; 57; 60)? What meaning and sense can the use of double-entry bookkeeping practice have if this bookkeeping – except for the presentation of extracts to the court in the case of litigation – was confidential and secret within the business? [1] The above-mentioned explanations for the emergence of double-entry bookkeeping techniques remain unsatisfactory in the end, unless at least decidedly economic intentions are also considered.

In contrast to the rather cultural-historical research approach that is recently domineering the discussion, the economic relevance of double-entry bookkeeping is highlighted again more strongly in the following. It is the aim of this contribution to carve out the importance of (double-entry) bookkeeping – interpreted as 'useful knowledge' for merchants – for the economic development in Europe and its possi-

[1] In the Medici Bank, for example, secrecy was taken so far that even when the contract was terminated or ended, all business documents – including the accounts – had to be returned to the ownership of the bank so that no one from outside could have a look at the accounts (Schneider 2016, 80).

ble indirect influence on economic growth by analysing examples of ledgers as 'mirrors' of their business's activities. As a result it should become clear that the useful knowledge of the technique of double-entry bookkeeping was one of the preconditions of the commercial and, later on, the industrial expansion of the Europeans, which made a significant difference to other merchant cultures in the world. Therefore, three central questions should be answered:

(1) How did bookkeeping contribute to reducing entrepreneurial risks in commerce and industry (cf. Orlandi 2018)?

(2) Did the expansion of knowledge about bookkeeping promote the expansion of commerce – or was it the opposite way around?

(3) What was the contribution of (double-entry) bookkeeping to the economic development in Europe? Did it influence economic growth? Can double-entry bookkeeping be seen as a precondition of industrialisation?

Before these questions are answered in a systematic way, a few key steps in the development of bookkeeping in pre-modern Europe are presented to lay the foundation for further argumentation. Thereby, one aspect is very important: «[A]lthough there was no standardisation of procedures, practices were common to accountants of different firms», whereby «not all firms or accountants adopted the new techniques learnt through oral or written exchanges» (Orlandi 2021, 536), and this applied equally for commercial entrepreneurs in Tuscany in the thirteenth century as well as in Upper Germany in the sixteenth or in England in the eighteenth century.

1. Steps in the development of bookkeeping in pre-modern Europe

1.1 The development of Bookkeeping in Italy during the Commercial Revolution

The main features of bookkeeping and accounting in use today can be traced back to developments that began in the cities of Upper Italy and Tuscany during the Commercial Revolution of the twelfth to fourteenth centuries. These Italian innovations in the field of bookkeeping were based on forms inherited from antiquity and handed down into the high middle ages: since the ancient oriental empires of Mesopotamia (since the Uruk Period, c.3100 B.C.; Pollock 1999, 5), the simple notation of individual business transactions served, on the one hand, as a personal reminder for the merchant, especially when he was involved in money and credit transactions as well as in long-distance trade. On the other hand, this compilation of business transactions, usually referred to in research as 'single-entry bookkeeping' and composed according to individual criteria, as was customary until the high middle ages, was also intended, if necessary, to prove the legality of his activity before the court, for example when he granted a (trade) credit to a foreign business partner from one year to the next (Arlinghaus 2006, 53; 56). The fact that this memorial function of bookkeeping and its testimonial power in court was accorded great importance, not least by the officials, is evidenced by the explicit reference to it in the *Corpus Iuris Civilis* compiled under Emperor Justinian I (527-565) between 528 and 534. This single-entry bookkeeping was sufficient for both the merchant of antiquity and the long-distance merchant of the early and high middle ages; the latter also accompanied his goods himself over long distances and required only a small written record of his activities, if any at all.

This situation changed with the expansion of trade of the Italian maritime cities since the ninth and tenth century and with that of the other Christian Western Mediterranean in the wake of the Crusades, which promoted especially the Levant and Orient trade, the maritime traffic required for this and the resulting payments. The protection of maritime transport through the novel type of premium-based marine insurance and the efficient processing of payments and credit by the cashless bill of exchange required, in return, a much more elaborate system of bookkeeping than which had previously been usual. At the same time, the once travelling long-distance merchants became resident merchants who progressively based their business activities outside their city on agents or factors and established partnerships or (trading) companies. They were therefore very reliant upon a system of bookkeeping and accounting that is increasingly exact as they were not allowed to lose control over their external transactions, which their factors carried abroad (Lane 1977; Arlinghaus 2002, 245) since they were answerable about profits and losses to their partners, i.e. investors (Carruthers and Espeland 1991, 43-46).[2] The fact that such simple account ledgers, as well as business correspondence, transformed into instruments of information and thus also of knowledge management are regarded crucial features in the background of the spreading of bookkeeping, along with the emergence of Italian merchant bankers operating throughout Europe, the increasing acceptance of credit, money economy becoming widespread in concert with a growing monetary stability since the thirteenth century and, quite practically, with the expanding availability of good paper as a cheap writing material since the second half of the thirteenth century (Sangster 2012, 98).

These early ledgers of individual business transactions were often not easy to understand due to their mostly low-level internal order and also displayed considerable regional peculiarities and differences (Antinori 2004). Since the turn of the thirteenth century[3], such ledgers were no longer sufficient for some resident merchants in Upper Italy and Tuscany, the internal order of such ledgers was gradually refined and thus adapted to the expanding business activity. The evolution of the debtors and creditors book began in the early thirteenth century (Orlandi 2021, 538-39), partly with entries in or from separate books, whereby credits appeared to be the most important and most critical and were therefore often specifically listed (profits,

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[2] It should be noted, however, that this early phase of improved commercial arithmetic was still based solely on calculation with Roman numerals and the thoroughly efficient use of the abacus (Hess 1977; Portet 2006, 55-7), even though knowledge of Indo-Arabic numerals became increasingly widespread from the turn of the twelfth to the thirteenth century, at least in the university-academic sphere, i.e. for mathematical, astronomical, and calendrical calculations (Durham 1992, 27-32). «The system caught on slowly, but it had enormous advantages for accounting, measuring, and calculating, and it was doubtless instrumental in the development of double-entry bookkeeping» (Mokyr 1990, 74).

[3] According to Mills (1994, 86), the business of merchants was already so extensive around 1200 that there was «a critical mass» and thus the need for double-entry bookkeeping, not least because of the ever more extensive transactions at the international fairs in Champagne. However, there is no empirical evidence for such an early beginning of the development of double-entry bookkeeping.

in contrast, were not) (Mills 1994, 84): «Credit dealings almost certainly were responsible for systematic accounting» (Yamey 1949, 103). The division into debit on the left page (*deve dare* – shall give) and credit on the right one (*ànne dato* – has given us, later: *deve avere* – shall have) as a tool for data processing did not have to take place on every page, but for practical reasons was often also carried out within an entire book (front – back, whereby the book was then turned upside down) (Arlinghaus 2006, 55; cf. Orlandi 2021, 539). Whereas formerly all items had been written down only once, the next step was to establish the habit that «all external transactions as well as all internal stock changes ... are recorded in two different accounts of a general ledger, one on the debit side (left) and one on the credit side (right). Both entries register the same amount but show it with different algebraic signs (debit and credit). Consequently, the total of all debit entries must equal the total of all credit entries» (Yamey 1995, 89-90).[4] Since the late thirteenth century, this system could be amended by additional account books, such as the cash book, the merchandise book, and the moveably property book (Orlandi 2021, 539-41).

In current Anglo-Saxon research, such rudimentary twofold accounting is called «dual-entry bookkeeping» and regarded an essential (intermediate) step towards actual double-entry bookkeeping, which can empirically proven to have happened for the first time in Florence at the turn of the fourteenth century. Double-entry bookkeeping in the full sense of the term first came to pass when ledgers and journals yielded information on where exactly the offsetting entry was to be found (Sangster 2016, 300; 302; 310; cf. Lee 1977). Different, separate accounts for specific goods or fields of business appear as yet another significant characteristic of double-entry bookkeeping, which has to be seen as fully developed by the end of the fifteenth century (Yamey 2000, 1; cf. Goldthwaite 2015, 626). And – not to forget – according to Federigo Melis (1950; 1972; Orlandi 2021, 541) the introduction of the surplus and deficit account could be seen as the decisive constitutive element of the double-entry bookkeeping. As the accountants at the Farolfi company used the surplus and deficit account as well as the capital account in 1299/1300, Orlandi (2021, 544) argues that «the double-entry method had already come into being by the end of the thirteenth century. … In the following decades, this accounting method spread among companies and merchant banking houses, with gradual improvements in its efficiency leading to the milestone of the introduction of the double-entry journal».

But when were the accounts balanced? In the vast majority of commercial enterprises, this was not a regular action, but rather done on demand, such as when the company was terminated pursuant to contract or in case of inheritance. Yet balances only were compulsory if a ledger was full and a new one had to be opened: then the balances of each account could be transferred to the new general ledger,[5] which was both laborious and time-consuming. Instead, only the most relevant balances were copied in the new ledger, while the introduction of a profit-and-loss account at the

[4] This passage refers to Giovanni Domenico Peri's work *Il negociante* (Venezia 1649), who defined double-entry bookkeeping in exactly this way.

[5] Such a *libro grande* «representated the definitive simplification of the procedure. It emerged from the old debtors and creditors book, which contained the merchandise book and, over time, basic accounts, and elementary or derivative accounts» (Orlandi 2021, 453).

time of balancing the individual accounts made it possible to close all those accounts that were no longer needed in the new general ledger (Yamey 1949, 107-09; 1991, 183). Above all, balances were made in preparation of a *bilancio del libro*, which, according to first evidences in the late fourteenth century, was a kind of prototype of an actual balance sheet, a 'trial balance', so to speak. The «techniques used for balance sheets were often crude» (Gervais 2016, 33), as can be seen several times in the *compania* of Francesco di Marco Datini and Toro di Berto, which existed from 1367 and 1373 (Arlinghaus 2000; 2002, 246): «Taking a trial balance as a test of equilibrium remains basic to double-entry bookkeeping» (DeRidder 2005, 14). Once this was achieved, it was only a small step to the general balance sheets, which were prepared comparatively rare since they were labour- and cost-intensive.

Yet, at least upon contractual termination of a trading company, such balancing through a profit-and-loss account was manadory (Yamey 1991, 183) so as to determine each participating partner's profit or loss. As late as in early-seventeenth century England, according to Richard Dafforne's *The Merchant's Mirrour* (1636, 48), a general balance was prepared only if the ledgers were full, the merchant died or went out of business (cf. Lane 1945, 165-8) as it had been the case in Italy in the fourteenth and fifteenth centuries.

The fact that the development towards a double-entry bookeeping took place exactly in the Upper-Italian-Tuscan area has been ascribed rightly to the innovative eco-nomic power of the Venice-Genoa-Florence-triangle. In Florence, the centre of wool and silk manufacture of that time, a habit had evolved to work with two types of ledgers, one for production and the other for trade (Mills 1994, 83-4). Here, where there were already at least six schools for bookkeeping in 1338, no manuals on the matter were written or published – unlike in Venice for instance – simply because there might have been no need to do so due to profound and widespread expertise in this field (Goldthwaite 2015, 623; Carruthers and Espeland 1991, 49; cf. Grendler 1989, 306-22). Genoa was among the nuclei of cashless payment and marine insurance, the intensive use of which required precise documentation of business transactions and therefore suggested the establishment of double-entry bookkeeping techniques.

The Massari account ledgers of the city of Genoa, surviving since 1340, are the oldest evidence of municipal double-entry bookkeeping (Chatfield 1977, 35). Venice, which, along with textile production and banking, maintained the largest trade network of the late middle ages that necessitated elaborate bookkeeping techniques, became the most important centre of book printing with moveable type in the second half of the fifteenth century together with Upper Germany ahead of Genoa and Florence, and thus also the most relevant distribution centre of information in this field for whole Europe (Mills 1994, 83-84; 88-92).

It is therefore significant that it was in Venice in 1494 where the classic treatise on accounting that set the standards for decades was published in printed form, namely in the *Summa de Arithmetica, Geometria, Proportioni et Proportionalità* (Venecia 1494) by the Franciscan Luca Pacioli (1445-1509).[6] Pacioli's work was not written for

[6] Here: First part, second section, tractatus XI: *Particularis de computis et scripturis*. – The fact that Pacioli was a Franciscan or Angelo Pietra (1550-1587) with his highly systematic book *Indirizzo degli*

his own use, but for the spreading of knowledge (Sangster 2012, 104) – which is aptly to be understood in the sense of 'useful knowledge' – and also achieved a very high degree of dissemination for the time (Sangster 2007, 143). Pacioli thus presented the first printed and relatively complete overview of the Venetian bookkeeping system of the late fifteenth century, which thus became the leading system in the whole of Western Europe (Yamey 1995, 90).

In this way, Pacioli's writings inspired ever new treatises on the art of bookkeeping in Italian, English, German, Flemish resp. French language from the 1540s onwards (Yamey 2004, 146-7; cf. Houtman-de Smedt 1991, 226). This work, purposefully 'advertised' by Pacioli himself, helped to install the Venetian form of double-entry bookkeeping as standardized and, in the long run, as the only guiding and common one, against which the Genoese or Tuscan forms stood back. According to the current state of research, the much older first German treatise on double-entry bookkeeping, written by Benedetto Cotrugli Raugeo (from Ragusa, 1416-1469) in Naples after 1451 in the thirteenth chapter of his work *Della Mercatura et del Mercante perfetto*, which was printed only after 1573 in Venice (Hernández Esteve 1992; Tucci 1990), did not achieve anything like a comparable circulation or status.[7]

1.2 The Diffusion of Italian bookkeeping techniques: Upper Germany as a case study[8]

Through the medium of moveable type printing, the 'new' technique was able to spread much faster than ever before from the turn of the sixteenth century. This, however, should cover up the fact that double-entry bookkeeping techniques had already found their way beyond Italy in earlier centuries as well. Ventures such as that of Francesco di Marco Datini, who were engaged on both sides of the Tyrrhenian Sea, quickly made Italian innovations known in Catalonia. In Castile, double-entry bookkeeping is first documented in 1465 among merchants of Burgos; from the 1520s it was a common practice throughout the country (Grommes 2008, 86). In Upper Germany, which is henceforth the focus of interest, the occasional merchant Ulrich Starck from Nuremberg could have been the first (or at least one of the first)

economi (Mantoua 1586) was a Benedictine is a circumstance that should not be overlooked. For the role and experience of monasteries and religious orders in the development of bookkeeping since the High Middle Ages – due to their ever-multiplying wealth and, above all, their diverse assets and types of revenues – has been of outstanding importance according to recent research on Italian, Spanish, and English case studies (Dobie 2008; Montrone and Chirieleison 2009; Maté Sadornil, Prieto Moreno and Santidrián Arroyo 2017), although still too little researched in detail.

[7] According to Sangster (2015b, 29), the section on bookkeeping in Cotrugli's book was only written posthumously – in1475 – by Marinu de Raphaeli in Naples.

[8] The fact that Upper Germany is chosen as an example is due to the author's current research, but also to the fact that in the sixteenth century the most surviving treatises on bookkeeping after Italian cities were written here (and in the Netherlands), in the first half of the century almost as many as in Italy and three times as many as in the Netherlands (Jeannin 1991, 259). This speaks for an outstanding interest in bookkeeping issues in the Upper German trading companies of the time. – Another very appropriate case study could be the development in Spain, for which Esteban Hernández Esteve made important contributions (Hernández Esteve 1996; 2009; 2011).

to practice the juxtaposition of services performed (commercial activity) and remuneration (payment) in his journal or manual respectively (1426-1435) (Penndorf 1913, 27), a technique that is also described in Marquart Mendel's *Buch der Hantierung* (1425-1438) (von Stromer 1965). However, a regular comparison of debit and credit can be found in a German merchant's journal as early as around 1390 and thus at the same time as Datini: the Nuremberg merchant Hilpolt Kress († 1406) practised it in his *Lange Puch*, which he kept in Venice and thus clearly under Italian influence (von Stromer 1967, 785-86).

In the German area, double-entry bookkeeping was originally not understood to denote keeping debit and credit entries, but rather keeping of two ledgers and copying entries from the journal to the general ledger (Kellenbenz 1971, 222). Thus since late fourteenth century, Nuremberg merchants at times kept several books in parallel, probably following the Italian model. A prime example of this early form of bookkeeping is that of Ulrich Meltinger, a Basel merchant active at the end of the fifteenth century, who kept account ledger entries in chronolgical order in principle, who kept his account book chronologically in principle, but summarised all business transactions with a business partner within the chronology, separating the journal, general ledger and debt ledger (Steinbrink 2007, 56). The debt ledger of the Basel merchant Ludwig Kilchmann (†1518), for example, was kept in such dual form (Signori 2014). The development of bookkeeping of the Great Ravensburg Trading Company, the paramount Upper German company of the time with intensive trade relations with most countries in Western and Southern Europe, was even more advanced: the few ledgers, which have survived since the 1470s, testify to a simultaneous use of various books, inventories carried out every three years and regular balancing of accounts in order to determine profit-and-loss, albeit without the indication of general and administrative costs. This finding applies equally to the Ravensburg headquarters and to the several branches (*Gelieger*). The systematic accounting already allowed for a plannable use of the invested capital (Schulte 1925, I 105; 109-10).

This brief and by no means complete finding demonstrates that – contrary to older research opinions[9] – at least dual bookkeeping techniques entered the bookkeeping practices of Upper German merchants rather early on, although they often were adapted and modified to the merchants' specific needs. In consequence, merchants from Italy and Germany produced books that were wholly or partly incomparable, so that scholars often faced the problem of having to compare different types of sources, which lead to the dictum of a certain backwardness of Upper Germans compared to the Italians. In case the books allow to to draw a meaningful comparison, however, only some minor differences can be detected (Weissen 2005, 172).

Prior to the publication of Pacioli's 'epochal' work in German in 1537, the transfer of such 'useful knowledge' to Germany took place primarily in two ways: firstly, through the *Pratiche di Mercatura*, which were the only possible books in the fourteenth and well into the fifteenth century, which were, however, usually written for personal use only; and secondly, through the exchange of knowledge in the wake of direct

[9] In particular de Roover (1948, 60): «The business methods of the German merchants were much more primitive than those of the Italians». This view was repeated so often that Braunstein (1964, 234) wrote: «Le retard allemande en la matière est bien connu».

business contacts and personal meetings, especially when prospective merchants from Upper Germany spent part of their apprenticeship in Italy and compiled a *Pratica di Mercatura* for themselves (Weissen 2005, 173-8; Denzel 2002; Häberlein 2014, 91).

Actually, the merchants of the late middle ages and early modern period – and this can duly be generalised – focused on learning through experience, observation, and imitation of their colleagues: «They learned through practice, not solely or even necessarily by studying, but by doing» (Safley 2020, 193). Training, commercial networks and the accumulation of experiential knowledge were thus largely responsible for the transfer of 'useful knowledge' in the trade sector: «The fact that bookkeeping and the development of financial instruments nonetheless indicate a level difference cannot be attributed to a refusal to progress, withdrawal, or even isolation. Rather, the Germans adopted and adapted very little from Italy, since their self-developed business practices were quite sufficient; they were also able to conduct their business with great success using simple banking means» (Weissen 2005, 178).

When the German translation of Pacioli's work apperared, it was particularly the textbook by the Venetian merchant Wolfgang Schweicker *Zwifach Buchhalten sampt seinen Giornal* (1549) that was closely based on Pacioli (Volmer 1929, 303), 'mediated' as it were by Domenico Manzoni's *Quaderno doppio col suo giornale* (Venezia 1540), which, without referring to him, essentially adopted Pacioli's remarks and which then became Schweicker's source (Kellenbenz 1975, 38).

The transition from German double-entry bookkeeping with journal, debt ledger, and general ledger or *kapus* to the Italian variant with journal and debt ledger can be exemplified by the bookkeeping of the Welser companies and their branches (*Faktoreien*): when the Welser-Vöhlin company was founded in 1496, it is highly probable that the *kapus* was still common practice in all branches. The *kapus* is documented in the debt ledgers of the Nuremberg and Memmingen branches as late as the 1520s, while the books in Antwerp were already kept in the Italian style by 1525. It can therefore be assumed that with the end of the Welser-Vöhlin company and the reorganisation by Bartholomäus V. Welser since around 1518, the Italian version could have been adopted at the major trading centres in Western Europe. The background to this could have been, on the one side, the incipient shift in emphasis from trade in goods to financial transactions, which made it advisable to use Italian-style double-entry bookkeeping. On the other, the increasing employment of foreign *Handelsdieners* (commercial clerks), who only knew the Italian system, could have led to this system being established in a growing number of branches. Experiences with trade organisation in Spain and a «general effort to simplify bookkeeping» could also have been important (Geffcken and Häberlein 2014, XXXI-XXXII). In any case, from the 1520s onwards, a «development process» can be observed, «which obviously first took hold in the branches at international trading centres such as Antwerp, then in those in the Holy Roman Empire and finally, from 1554 onwards, also at the company headquarters» (Geffcken and Häberlein 2014, XXXI).

Despite simple bookkeeping was still satisfactory for many companies in the sixteenth and seventeenth centuries (Weissen 2005, 172-73) and the possibilities of dual or double-entry bookkeeping were often not or only partially exploited (Carruthers and Espeland 1991, pp. 39-40; 87), double-entry bookkeeping in the Italian style is documented in all enterprises (examined in this article) of Upper German high finance in the sixteenth century, although with clearly differentiated and exact implementation.

The 'pinnacle' of bookkeeping in Upper Germany, as in Italy, was the periodic balancing or general accounts (*Generalrechnungen*). They summarised the business results of a particular period and – not always, but ideally – drew up a profit-and-loss account, i.e. the company's results were shown in the balance sheet. The periods for such general accounts varied greatly from company to company they were usually drawn up when a company contract expired – often after two to six years – in order to be able to allocate profit or loss to each investor. However, the death or withdrawal of a significant shareholder, the addition of a possible successor or other drastic events could also call for a general account. However, the balance sheet could also be reviewed again, as had been the case with the Fuggers since 1546: after the balance sheet had been closed, a *proba*, a kind of control statement, was prepared, which had an essential and, above all, a completely new role in the entire bookkeeping business. Such a proba was intended to enable a capital comparison, a review and, if necessary, profit-and-loss adjustment, as well as control and cross-checking, and most likely also the planning of future business activities (Isenmann 2019, 153; 157-62).[10]

1.3 Some developments in bookkeeping in the run-up to the Industrial Revolution

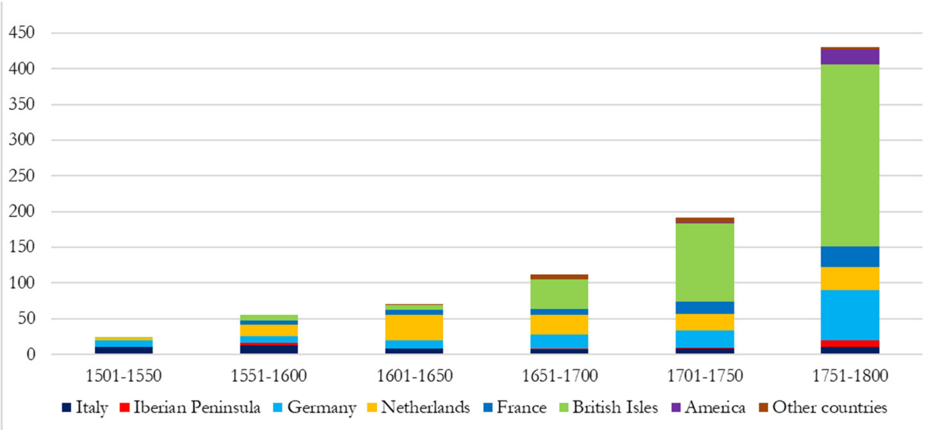
Whereas the theoretical reception of Italian accounting techniques north of the Alps had begun in the 1540s (see above), the publication of treatises on accounting from the seventeenth century onwards was progressively concentrated in Northwestern Europe and then, in the eighteenth century, specifically and foremostly in England, with a dramatic increase in the number of these writings (Graph 1) (Jeannin 1991, 259).

The background to this development is, on the one side, the process of commercialisation that began in Northwestern Europe in the late sixteenth century and culminated in the Second Commercial Revolution at the turn of the eighteenth century, on the other side, the quest for knowledge and theoretical penetration in the course of the «Industrial Enlightenment» (Mokyr 2016, 189, 339) and the Knowledge Revolution, and lastly – directly related to this – the beginning of the industrialisation process in eighteenth century England. The theoretical preoccupation with (double-entry) bookkeeping and therefore the production of 'useful knowledge' in this area was concentrated – as it had been in the late middle ages – in the economically leading regions of Europe, i.e. in the first half of the seventeenth century in the Netherlands, then and notably in the eighteenth century in industrialising England, whereas in the Holy Roman Empire the number of publications only began to rise in the 1780s – with the first steps towards industrialisation. In contrast, only comparatively few relevant works appeared in the Mediterranean countries after the sixteenth century.

[10] An analysis of all available Fugger balances and the corresponding *probae* is currently being carried out by Mechthild Isenmann and the author. The publication of the results is expected for 2024.

Even though single-entry and double-entry bookkeeping were still used by businesses well into the industrial era (e.g. Houtman-de Smedt 1991, 225), it is still worth asking which remarkable new developments compared to the state of accounting techniques in the sixteenth century can be found in these Northwest European treatises of the seventeenth and eighteenth centuries.

Graph 1. **Bookkeeping treatises published, 1500-1800, per country**



In his *Vorstelicke bouckhouding* (Leyden 1607), the Flemish mathematician, physicist and engineer Simon Stevin (1548/49-1620) was probably the first to indicate that the separation of individual accounts in double-entry bookkeeping had two advantages: on the one hand, it was possible to see at any time how much of a particular commodity was in stock; on the other hand, it was possible to calculate the profit or loss resulting exactly from transactions with this commodity. The resulting usefulness is evident. At the same time, important information could be derived that the merchant could use for the calculation of commissions or the distribution of income to the investors, which Yamey (2000, 4-5) also explicitly points out. From the end of the seventeenth century at the latest, evidence began to accumulate according to which bookkeeping was not only understood as a justification and legitimisation of transactions, but also as a way of improving the quality of decisions made by commercial entrepreneurs (Carruthers and Espeland 1991, 58). However, this research finding should not obscure the fact that already in the sixteenth century and earlier at least some commercial entrepreneurs used their accounting to improve their business planning and strategies – for example in the sense of minimising risk. From Upper Germany, for example, Anton Fugger can be described as such an innovative merchant banker (even if the research on this has not yet been fully completed), who used the detailed and elaborate bookkeeping of his trading company in this sense around the middle of the sixteenth century. This 'use' of double-entry bookkeeping undoubtedly also contributed to its increasingly widespread use.

Another decisive factor for the increased use of double-entry accounting techniques, including periodic, soon to be annual balancing, was the need to pay dividends and the interest of investors in profit or loss. Both encouraged the rapid spread of double-entry accounting techniques and, in consequence, the booming theoretical study of the subject (DeRidder 2005, 15-16). The joint-stock companies that emerged in the Northwest European countries from the seventeenth century onwards can be seen as pioneers of this development.

Furthermore, the information content of the books kept grew by both increasing their numbers and thus differentiating them more thematically. In the eighteenth century, for example, special bill (of exchange) books were virtually a matter of course, in many companies there were also forwarding or freight books, and, on top of that, in Central Europe there were journals in a smaller, handy 'pocket book' format for visiting trade fairs ('trade fair books') and many other special features. All these specialised books did not provide aggregated data, but were directly related to the individual transaction, comparable to extensive general ledgers, but were not intermixed (by adherence to a chronological order) as in a journal. They therefore provided very specific information on a particular business area (which, incidentally, makes them exceptionally informative for historians). However, the accounts in the general ledgers tended to be more and more differentiated in order to make the information content of the individual entries more precise. One example may suffice: in his treatise *La science des négocians et teneurs de livres* (Paris 1704), the French mathematician Mathieu de la Porte (†1722) distinguished three categories of accounts in general ledgers. The principal's accounts comprised all capital flows and profits, including all banking and insurance transactions. The effets effectifs listed cash and cash transactions, the turnover of goods, stocks, bonds and bills of exchange transactions, as well as real estate and inventory. Finally, the compte des correspondants were personal accounts related to the business partners (Houtman-de Smedt 1991, 234-35).

Of course, the increasingly relevant asset valuations and calculations of an enterprise's profit were not standardised (Yamey 1991, 182). «Before the [industrial] evolution, fixed assets were insignificant but, with the growth of industry, became an important cost of production and distribution» (DeRidder 2005, 17). Independent costing is thus often only associated with the industrial production mode, as it now became important – in contrast to the trade of the previous centuries – how high the costs for a piece of produced goods actually were. The distinction between factory bookkeeping or costing, which became more critical in the eighteenth century as a result of the industrialisation process, and traditional commercial or financial accounting is not, however, fundamentally new. Approaches to this can already be found in fourteenth century Italy – for instance, among the cloth producers of Florence and Tuscany – which, however, were always limited to partial areas of business activity. Yet even in England in the late sixteenth and early seventeenth centuries, detailed cost accounts can be found, for example for the copper and silver production of Daniel Höchstetter at Keswick (Hemmeryley 1988, esp. 117-18; cf. Donald 1955, 221-30). And in the case of English textile producers in the early eighteenth century, there were not only more or less regular balance sheets – in at least one case even weekly ('weekly profit') – but also numerous direct costing calculations by the middle of the century at the latest (Edwards and Newell 1991, 43). The fact that costing calculations can be traced to a much lesser extent and usually much later than other accounting techniques seems to be due not least to the fact that «costing records ... were kept separate from other account books, and were often written-up as loose-leaf memoranda» (Edwards and Newell 1991, 38), as which they were quickly lost or deliberately destroyed.

These few examples highlight one thing clearly: even if the further development of accounting and its theory into the modern era was decisively driven by the economic and institutional challenges of the Industrial Revolution, the development of the railway system and then finally of business taxation, and was accompanied by the increasing importance of fixed capital (DeRidder 2005, 16-17), the elementary foundations had not only been developed in the pre-industrial era, but had also already been practised, albeit not always with the same stringency as should be required under the conditions of industrial economic activity.

2. Bookkeeping: a 'key technology' of pre-modern commerce?

After the three main questions presented at the beginning of this article, the second step is to analyse whether and, if so, how and to what extent bookkeeping can be used

(1) as a factor of the expansion of commerce,
(2) as a medium of the reduction of entrepreneurial risks, and
(3) as an instrument of vitalisation of economic growth.

(1) As exhibited in the first part of this article, the developmental process of bookkeeping in Italy during the Commercial Revolution was closely intertwined with the expansion of trade, payments, maritime transport and insurance over the centuries. The emergence of ever more elaborate bookkeeping techniques appears not least as a reaction of merchants to the ever greater financial-technical challenges of their trading activities, which were to be documented with ever greater (arithmetical) precision and differentiation in order to be available – first of all – as a medium of information and memory within the company, especially when the principal had no direct insight into the business conduct of, for example, a branch abroad due to geographical distance (Yamey 1991, 183). However, the action mechanism also worked in the opposite direction: the ever more refined bookkeeping also made possible a further expansion of trade in all its facets, both in its scope and in its geographical dimensions, since the inherent control mechanisms offered protection against distant employees or business partners, for example, and significantly reduced the risks of far-reaching long-distance trade without the personal travel activity of the merchant or head of a commercial enterprise.

As an example, let us once again look at the interplay between trade and bookkeeping in Upper Germany: as already mentioned, the expansion of international trade since the fourteenth century was accompanied by the adoption of Italian bookkeeping techniques. This learning process took place in the wake of the training of northern Alpine merchants in commercial arithmetic and accounting in Upper Italian and Tuscan trading and financial centres (Mokyr 1990, 189). Even if the Upper

German merchant bankers initially developed their own form of so-called German double-entry bookkeeping (see above), which was tailored to their commercial requirements, the temporal connection and the business-specific differentiation of the various techniques with the expansion of their international trade relations in the fifteenth century tends to be unmistakable, as the example of the Great Ravensburg Trading Company shows. At the beginning of the sixteenth century, when the process of commercialisation intensified considerably, such bookkeeping no longer seems to have been sufficient to coordinate international business activities on a large scale, which is the reason why the Upper German trading companies gradually switched to dual and then double-entry bookkeeping, in the case of the Welsers, as displayed, in the 1520s (see above). The greater the challenges in trade and finance became, the more this double-entry bookkeeping was then refined or rounded off by drawing up balance sheets, the accuracy of which was finally even checked by a proba in the case of the Fugger at the height of the restructuring of their business. Even in later times of declining trading activity, the Upper German trading companies and sole proprietorships did not fall behind this 'standard' of double-entry bookkeeping practice.

However, commercial activity and its expansion also promoted two monetary aspects: on the one hand, the use of a certain money of account or later bank money as a unit of account in the books was a good way to (largely) exclude inflationary tendencies to which the exchange currencies were subjected (Sangster 2016, 309-10). The fact that Upper German merchant houses in the sixteenth century regularly kept their books in the accounting money florins Rhenish, and Italian and Spanish ones in the accounting moneys used there, is clear evidence of this practice, which was often practised to safeguard their own trading activities. In many cases, however, it was also usual to keep accounts in two different currencies – as was the case with Simon Ruiz from Medina del Campo – in order to reveal the amount and direction of the debt between two business partners or between the headquarters and a branch. In this way, the amount of profit or loss for the principal was also clearly visible when converting between the different currencies (Yamey 2011, 127; 141).

On the other hand – and this seems even more important from a long-term, macroeconomic perspective – the dual system of bookkeeping all'italiana already enabled the creation of book money and thus the expansion of the money supply in a continent poor in precious metals. By means of book transfers between personal accounts (Lee 1973, 137-9; Yamey 2012), payments could be settled, funds transferred or bills of exchange cleared without the flow of cash (Arlinghaus 2006, 51), thus expanding the quantity of book money by a merchant banker providing a business partner with credit on his 'transaction account' (in modern terms). In the long run, book-entry or book money gained a much higher share of the total money in circulation for payment purposes than cash. The use of book money also reduced the risk of fluctuations in value, as with coins, transport costs and the danger of robbery (LeGoff 2011, 157-8), not to mention the risk of insolvency of the 'bank'. As the authorities were unable to provide sufficient cash, i.e. coinage, for expanding trade due to the low availability of precious metals, which was reflected in the bullion famine of the fifteenth century and consequently in an economic recession in wide parts of Western Europe (Day 1978; Kindleberger 1984, 17-26; Spufford 1993;

Campbell 2016, 334; 367-9), the economically potent merchant bankers resorted to the creation of book money to compensate for this bullion famine.

The fact that in the late fourteenth and especially in the fifteenth century, when the bullion famine became more noticeable in trade and deflationary tendencies threatened to limit commercial activity, the techniques of dual or double-entry bookkeeping became more widespread and can be traced in more and more trade businesses – also outside Italy – is a significant sign of the increasing importance of book money in the commercial economy and the growing awareness of merchant bankers that they could make use of this easy-to-create means of payment. This technique of money creation by means of bookkeeping had been provided since the late sixteenth and especially in the seventeenth century by public banks in Venice (*Banco Giro*), Amsterdam (*Wisselbank*), Hamburg and Nuremberg (*Banco Publico*) as a public infrastructure for international cashless payments by means of book money in their own currencies. In doing so, they were supposed to increase the efficiency of their cities' trade and ensure monetary stability (North 1997, 39; 2003, 223; Denzel 2012, 54-5, 97). These giro banks thus already fulfilled essential functions of modern central banks (Denzel 2018).

(2) It can thus be stated: bookkeeping contributed to reducing entrepreneurial risks. This statement refers to four factors that were of essential importance within a commercial enterprise or for a merchant: first, his own memory of business transactions; second, the arithmetic correctness of the accounting of individual business transactions; third, the predictability of strategic decisions; and fourth, the profitability of the enterprise. These factors were able to significantly mitigate the entrepreneurial risk or – in the case of profitability – even overcome it.

Even simple bookkeeping could not exclude the high risks of maritime trade or credit transactions, but it at least protected the merchant from the danger of being forgotten and possibly from unjustified condemnation in court and could thus grant the enterprise a minimum of security. This finding of the memorial function is, of course, not limited to the period up to the tirteenth century, but is also valid without restriction for later centuries up to the time of industrialisation and its weighty significance has been proven (Lemarchand, McWatters and Pinau-Defois 2014)

With the *revolution du commerce* (Henri Pirenne), the importance of arithmetic, i.e. the arithmetic correctness of the accounting of individual business transactions, was added as a further relevant factor for reducing commercial risk. The more arithmetically accurate the bookkeeping was, the lower the risk of disputes among the partners and the more stringent the control mechanisms could be towards trade agents. Yamey (1991, 185) is right when he states: «A merchant's own account books, in whatever form or on whatever system these were kept, could not enable him to prevent a distant agent from being dishonest, extravagant or inefficient»; but if the principal also had information on prices, exchange rates, costs, etc., controls of the agent's accounts were certainly possible and were carried out, as exemplified by the Fuggers' action against their factor in Spain, Andreas Hyrus, who had falsified invoices, embezzled funds and carried out forbidden transactions on his own account (Haberer 1995, 147-54). It is not without reason that Mandrou (1969/1997, 193) noted for the Fugger bookkeeping that it «testifies to the solid economic management of upper middle-class merchants who have long since recognised that an exact overview is the best prerequisite for a successful course of business».

Thus, the development of commercial records towards double-entry bookkeeping can also be interpreted as a process of ever further risk reduction: because on the one side, the possibility of balancing made it possible to check the accounting accuracy and correct it if necessary; on the other side, the differentiation of the various personal or general ledger accounts offered the opportunity to check the individual branches of business for their earnings. Such random checks, which are quite common in Italian ledgers (Goldthwaite 2015, 628), could not least be seen as a first basis for being able to plan future business activities more stringently than before, when, for example, business branches or partners were no longer taken into account due to insufficient earnings and others with positive earnings were expanded.

Yamey (1949, 109) had already emphasised that «the profit-and-loss account therefore contained a hotch-potch of entries besides those of business gains and losses». This measure of introducing a profit-and-loss account, which was actually initially a technical accounting measure, had the positive effect that the merchant could now learn how his business – or at least the respective part of the business – was doing financially, whether he had made a loss or a profit. Whether "profit calculations were not as useful for traders in the early modern era as they would be now" (Gervais 2016, 34) cannot perhaps be conclusively clarified, but it is undeniable that periodic profit calculations had already been made in commercial enterprises since the first half of the fourteenth century, for example by the Alberti of Florence (de Roover 1958, 34). The (early) Fugger inventories can also be interpreted in this sense (Yamey 1964, 120). Why should merchant bankers have made profit calculations with the help of a profit-and-loss account if they did not want to use it or did not know how to use it? The extensive work behind such calculations, some of it over 100 pages long, becomes clear and comprehensible in detail from the ledgers of the Fugger accounts. In this way, precise and detailed accounting and a balanced assessment of the individual bookkeeping items made clear decisions possible for the further strategic approach of a business's management. This included in particular the differentiation between «good», «doubtful» and «bad», i.e. ultimately «lost debts», as can be seen for example in the bookkeeping of the Constance Grimmel (Nutz 1996).

Of comparable, if not even greater, relevance was the possibility of assessing the value of the individual balance sheet items: Anton Fugger regularly made such assessments in marginal amounts, very critically and rather to his disadvantage, so as not to make his company look good (Isenmann 2019). His Augsburg competitor Ambrosius Höchstetter, in contrast, seems to have acted in the opposite way and rather 'doctored' his accounts in his favour (Safley 2020, 101-29). Anton Fugger had been practising this valuation or control (revision) of the individual items since his apprenticeship in Italy, especially since the individual branches often overstated the value of their inventories. However, he also used this method to make the presentation of the individual entries ever more concise (Isenmann 2019, 157-8). In the development of Fugger bookkeeping, this striving for ever greater clarity was perfected by a growing scarcity and summary of information, at the latest since the general account of 1546. Even if these are only individual examples for the time being,[11] an essential purpose of double-entry bookkeeping can be seen in the improvement of decision-making, in the calculation of profit-and-loss, of claims and liabilities of the individual capital investor as well as in the greater control of internal and external transactions (cf. Derks 2008), admittedly without wanting to absolutize these crucial functions in a Weberian or Sombartian sense or to interpret them in terms of an imaginary connection to capitalism and rationality. However, a reduction of entrepreneurial risks was in any case associated with the aforementioned possibilities for using bookkeeping.

(3) But did the advantages of double-entry bookkeeping that were pointed out and asserted also provide a stimulus for the economy as a whole and its growth? Even if bookkeeping alone did not guarantee entrepreneurial success, it was able to give commercial and later also industrial enterprises a certain inner stability that could certainly promote entrepreneurial success in the long term. Particularly in internal and external crisis situations, accounting could represent the decisive information and planning basis for short-term crisis and long-term resilience management (cf. Denzel 2020), as it can be regarded as a decisive instrument of entrepreneurial resiliencing anyway, according to recent research on Upper German case studies from the sixteenth and early seventeenth centuries (Denzel 2022). And this also applies in the reverse perspective: it is not without reason that inadequate (double-entry) bookkeeping and above all a lack of regular accounting was at least one of the main causes of the failure of several Upper German trading companies that went bankrupt in the course of the sixteenth century, and this was already recognised by expert contemporaries (Denzel 2022). Despite all the uncertainties and imponderables inherent in the accounts, they were, according to Houtman-de Smedt (1991, 241), «instrumental pour la constatation en bon temps de symptômes de maladies dans une entreprise. ... Une diagnose opportune offrirait l'avantage de pouvoir prendre des mesures de correction de trajectoire et de par là sauver éventuellement l'entreprise de la banqueroutte».

Resilient enterprises – be it in trade or in manufacturing – which were able to overcome crises and perhaps even emerged strengthened from them, could in turn form a remarkable support for positive overall economic development, because, understood in this way, the term 'resilience' indicates 'recovery capacity' and 'development on a new basis' in the field of economy. From such a perspective, the practice of double-entry bookkeeping with all its possibilities of providing and evaluating information can at least be said to have made a positive indirect contribution to positive macroeconomic development – in the broadest sense: growth – in the pre-industrial as well as in the industrial era. Especially in the industrial sector, the question of production costs and thus costing has played a decisive role since the eighteenth century. The contribution of double-entry bookkeeping to macroeconomic growth trends can, of course, neither be measured nor calculated, but rather appears as a soft

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[11] The extent to which this finding is also valid for other Upper German trading companies of the fifteenth to seventeenth centuries must (still) be left open here, as a comparably comprehensive source material of this special kind has not survived (or been known until now) for any other enterprise. Future research by Mechthild Isenmann and the author will address this problem.

factor, which, however, should by no means be neglected, notably when it comes to the relevance of the commercial sector for the onset of the industrialisation process. Even if double-entry bookkeeping is not necessarily to be seen as a precondition of industrialisation, it at least secured this process from the business's internal perspective, provided a stable framework for corporate information management and enabled scope for shaping and developing industrial production through costing.

Conclusion

The aim of this article was to re-emphasise the economic significance of the development of double-entry bookkeeping much more strongly than is currently the case in the mainstream of research, which underscores organisational and cultural aspects while paying little attention to economic components (e.g. Gervais 2016). Without wanting to derogate these new research results, it should be reiterated that the gradual formation of double-entry bookkeeping techniques in Italy during the Commercial Revolution and their spread across large parts of Europe and the European-dominated world in the following century were also accompanied by economic factors and consequences, the scope of which should not (any longer) be interpreted in the Weberian or Sombartian sense of a foundation of capitalism, but should also not be forgotten or suppressed. And another important aspect has to be pointed out: Contrary to what Yamey (1949, 127-28) argued some decades ago, the development of bookkeeping in Tuscany and Northern Italy «did not produce a clear distinction between new and old accounting methods», but «was characterised by gradual and contradictionary changes that spread the double-entry method among accountants and managers» (Orlandi 2021, 544).

Double-entry bookkeeping has a far greater significance than being «a system of organising business information» and «a link between medieval and modern business practice» (Yamey 1991, 187; 163). It is an innovative 'key technology' in commercial practice (not only pre-modern!) and undoubtedly a usefull knowledge for the commercial as well as the industrial entrepreneur. The following advantages of double-entry bookkeeping compared to single-entry bookkeeping techniques are to be noted:

Beyond the pure information management, which could be seen as a (not the!) «main purpose of accounting» (cf. DeRidder 2005, 15), double-entry bookkeeping

- made the exact arithmetical control of business operations possible (cf. Orlandi 2021, 544), although these were kept in various currencies, bank or accounting moneys;
- offered a (largely) secure framework for internal account clearing between business partners and thus for the creation of book money (thus forming one of the foundations of an extensive private and public banking sector);
- enabled the production of profit-and-loss accounts and finally of balance sheets, which made it possible to control the use of the capital invested in a company and the profitability of the enterprise or of one of its parts;
- let the entrepreneur establish and balance single successes; the balance sheet, based on extensive inventory, made it possible to produce precise statements

about the employment of corporate capital (assets) as well as the source of funds (liabilities) – the claims of entrepreneurs and debtors; and, last, but not least,
- provided the basics of an accurate costing in industrial production.

These mechanisms offered the commercial and later the industrial entrepreneur the chance to check the profitability of his actions, to mitigate his manifold risks and to make his enterprise organisationally resilient – whether he actually made use of these opportunities is, of course, often not known. The fact that inadequate bookkeeping and incorrect or missing balancing were regarded as important reasons for bankruptcy can be proven at least by various Upper German case studies. The Upper German merchants who explicitly expressed such assessments – for example in court or in bankruptcy proceedings – were therefore considered to have at least practical knowledge and application of double-entry bookkeeping and balancing as useful knowledge for the successful practice of their profession.

When double-entry bookkeeping is described here as a 'key technolgy' of pre-modern commerce, it is almost self-evident that it had a different effect than 'classical' technical inventions or processes such as mechanical wire drawing, the printing press, the Spinning Jenny, the steam engine or the puddling process. The innovative accounting techniques had more of an indirect and hedging effect on the expansion of trade in Europe and beyond by helping to reduce entrepreneurial risk, at least in part. This is a considerable structural and qualitative difference from, for example, the much-documented peddling or caravan trade in the Indo-Asian region (Steensgaard 1973), which did not have such accounting mechanisms. Even if it is by no means to be claimed here that the development of double-entry bookkeeping techniques was a prerequisite or basis for European expansion, it was nonetheless an instrument that supported, controlled, and safeguarded the developing intercontinental trade, which made it possible to manage correct and reliable accounts, for example in cashless payment transactions, quickly and without great effort, even over the longest distances. In the seventeenth and eighteenth centuries, this was evidenced by the manifold monetary and exchange transactions between Asia and Europe that were conducted within the European East India companies, as well as the transatlantic business activities of Western European trading houses.

This finding, which can be noted for European and intercontinental trade, applies equally to the expansion of commercial production in the eighteenth century and later, which was also supported by bookkeeping and included costing. As it were, forming a reliable arithmetical and planning framework in the background of commercial and later industrial development, it ultimately also made an indirect, albeit unquantifiable, contribution to economic growth in Europe – entirely in the sense of the contribution of useful knowledge to economic growth that can be stated in principle (cf. Mokyr 2016, 339-41).

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Måns Jansson, Göran Rydén

The œconomia of iron and steel. Material transformations, manual skills, and technical improvement in early modern Sweden[*]

1. Introduction

In the preface to *Regnum subterraneum sive minerale de ferro*, from 1734, the Swedish philosopher and mining official Emanuel Swedenborg placed his ambitious text within a framework of proto-enlightenment ideals, stating that it should be in the interest of all individuals to «contribute to sciences and professions coming to a richer prosperity» (Swedenborg 1923, xxvi). He took aim at the advancing «field of metallurgical science», more precisely the processing of iron. *De Ferro* was divided into three parts, sequentially introducing the reader to production methods, assaying, and chemical experiments. This order was not chosen at random, as the author stated that an improved understanding of work processes provided a sound foundation for knowledge about finding «riches and treasures hidden in the ores, and make fuller use of them», while also enabling «as much experimentation as chemical science with its furnaces and abundance of appliances» (Swedenborg 1923, xxiv). Thus, Swedenborg imagined a bottom-up process, starting with the procedures by which nature was transformed into useful matter by working men.

Swedenborg was indeed not alone in stressing the materiality of work as the basis for metallurgical inquiries. In France, René Antoine Ferchault de Réaumur promoted «ingenious practices» attached to the «manipulation» of nature. Rejecting old alchemical principles, his work gave inputs to the «practical investigation of materials», but it also «made the body of the artisan a subject of observation and experimentation». Embodying these values, *L'art de convertir le fer forgé en acier*, from 1722, linked the pursuit for improvements in the iron and steel trade with ideas of a general «technical and economic advancement», put into motion by the uniting efforts of learned men and benevolent politics (Bertucci 2017, 54-5; 61-8). Similar endeavours took place in the German lands, where, according to Ursula Klein (2012; 2017), «savant officials» of cameralist administrations played crucial parts in shaping the evolving field of metallurgical expertise.

Réaumur's book provided inspiration for Swedenborg, with references and transcripts being made throughout *De Ferro* (Zenzén 1923, xvi; Fors 2015, 96-7). However, there were areas where the two authors differed, notably so regarding artisanal work. Réaumur, despite his emphasis on metalworking practice, distanced

[*] The authors gratefully acknowledge financial support from Jernkontoret (*Stiftelsen Marie Nissers fond för bergshistorisk forskning*).

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Referee List (DOI 10.36253/fup_referee_list)
FUP Best Practice in Scholarly Publishing (DOI 10.36253/fup_best_practice)

Måns Jansson, Göran Rydén, *The œconomia of iron and steel: Material transformations, manual skills, and technical improvement in early modern Sweden*, © Author(s), CC BY 4.0, DOI 10.36253/979-12-215-0092-9.15, in Giampiero Nigro (edited by), *L'economia della conoscenza: innovazione, produttività e crescita economica nei secoli XIII-XVIII / The knowledge economy: innovation, productivity and economic growth,13th to 18th century*, pp. 237-262, 2023, published by Firenze University Press, ISBN 979-12-215-0092-9, DOI 10.36253/979-12-215-0092-9

himself from artisans, whom he saw as «automata» and «obstacles to the encyclopedic endeavour» (Bertucci 2017, 55). Inventions would instead be spread from «the savant's laboratory» in a top-down fashion (Bertucci 2017, 74), primarily benefitting those «who can put artisans to work, just as artisans can put their tools to work» (Réaumur 1956, 8). Swedenborg connected craftwork to knowledge-making in a somewhat more nuanced way, stressing that the know-how of «smiths, smelters, and suchlike professionals» should be «preferred or at least equated with much scientific insight», since it was «altogether connected with the actual work». Consulting artisans' «experience and knowledge», from the «practical domain», was thus a key in making «countless of secrets» known to the «scientific world». Still, and in line with Réaumur, this was not the same as to suppose anything «brilliant or ingenious» to arise out of the metalworkers' everyday toil; they were, after all, «simple people with sooty faces like the Cyclops». Moreover, the wider spread of useful know-how could hardly be entrusted to those involved in the «making of metals». Trade secrets held sway among artisans, and some of them went to great lengths to guard skills and technical competencies, thereby «withholding them from the eyes of working peers» (Swedenborg 1923, xxiv-xxv).

Unlike this «envious group» of people, members of «the society of learned Muses», to which Swedenborg included himself, would never evade from bringing valuable knowledge into public light (Swedenborg 1923, xxv-xxvi). The metal trades, being of considerable economic interest to early modern European states, was a well-chosen area for such a project. Swedenborg had gathered an extensive experience from working within the Swedish Board of Mines (*Bergskollegium*), a state organ that was deeply involved in the cross-border circulation of technical knowledge (Fors and Orrje 2019). In 1716, he was elected to an extraordinary position in the Board and from 1724, he held a permanent position as *assessor*. He made several tours in Sweden, inspecting mines and ironworks, and also travelled in Europe, gathering information about metalworking (Zenzén 1923, xiv-xv; Dunér 2013-19, 498-500; Fors 2015, 83-97).

Swedenborg's practical experiences are reflected in the rich palette of techniques described in *De Ferro*, with Sweden at the centre, but with detours to Europe. Read along other eighteenth-century printed treatises and handwritten memos, the book highlights the complex set of work methods that formed the basis of metal processing. This body of written sources informs us about, with Ursula Klein and Emma C. Spary's (2010, 19) words, «the continuous trafficking between material manipulations, explanations, and uses, and … the various purposes served by made materials and claims to material expertise.» Zooming in on the making and adaptation of iron and steel, our text proceeds from such an objective, as it aims to scrutinise the changing interplay between manual practices, nature, and technology within the early modern knowledge economy. In doing so, we show how the working of metals in furnaces and forges was closely related to ideas of improvement in the northern outskirts of enlightenment Europe. Moreover, our discussion provides insights into the interactions between material makings and perceptions of work in a society that was still, albeit to a gradually lesser extent, dominated by ideas of a divine order.

The materiality of knowledge-making in early modern societies has been increasingly debated by scholars from various disciplines, with several publications breaking new ground in highlighting activities and movements at the basis of industrial and scientific developments. Some have bridged the spheres of «hand» and «mind», or practice and theory, by exploring links between manual work and theoretical knowledge. Others have nuanced previous understandings of one-way transfers by analysing the circulation of skills, ideas, and objects across geographical distances and social divides (e.g., Roberts, Schaffer, and Dear 2007; Davids and De Munck 2014; Smith 2019a). Metal processing is at the heart of these discussions. As noted by Pamela O. Long, mines and metalworking sites were important «trading zones» in the pre-industrial knowledge economy, stimulating encounters between learned men, officials, and artisans, while also promoting the diffusion of «practical know-how and technological expertise» through written treatises. Thus, the metal sector became a field for technical projects, linked to visions of military power and economic betterment, but it also «created disciplines of learning suitable for a readership of both the wellborn and the technically skilled.» (Long, 2001, 208-9; 2011, 107-12). Klein has similarly used the metal trades to discuss the consolidation of academic, administrative, and artisanal domains in eighteenth-century Europe. Highlighting the doings of state-employed «hybrid experts», she stresses how metalworking localities became sites for «technical work and technological research» as well as «systematic natural observation and experimentation», at the same time as «methods and experience acquired in practical contexts» gave rise to «exact and analysing natural sciences» (Klein 2017, 303).

Three aspects from previous research are of particular interest, as they place focus on useful knowledge within the «practical domain», while at the same time enabling discussions of long-term changes in a broader context of knowledge-making. First, craft skills and manual methods need to be placed at the centre of analysis. According to Pamela Smith, artisans' bodily engagement with nature and epistemological claims gave decisive input to the development of «an active science» from the sixteenth century, one that «came to include the production of effects, or productive knowledge». Thus, emerging linkages between «*episteme*, *praxis*, and *technē*» during the early modern period were built on the workshop-based shaping of a «vernacular 'science' of matter» by skilled craftspeople (Smith 2004, 7-8, 17-19). Smith has also stressed the connectedness of metalworking techniques, like measurement and testing, and «empirical practices» employed in emerging sciences (Smith 2010, 31-5; 2014, 18). More specifically, in relation to steelmaking, Phillippe Dillmann *et al* (2011, 15-19) has accentuated that the refinement of iron into steel linked «analytical science and operational knowledge».

In tandem with innovative achievements in the eighteenth-century metal sector, artisanal procedures gradually came into focus for investigation and negotiation. Many craftsmen, as proven by French cases, took active part in this changing context of skilled work, contributing to the formation of «specific patterns of open knowledge» (Hilaire-Pérez 2007, 137, 139-43; Pérez 2008, 234-36) and promoting the importance of «sensorial intelligence» to academies and state authorities (Bertucci 2017, 158-60). Similar examples can be shown from other parts of Europe, such as Sweden, where state-supported metal manufacturers played key roles in disseminating new working methods (e.g, Jansson 2017). On the one hand, this development gave rise to standardisation and the launching of organisational schemes not favoured by working people, although we should not, as Ken Alder (1997, 146-53) points out, equate these measures with 'deskilling'. On the other hand, the interest in understanding and categorising the manifold operations employed to refine natural resources were significant in nurturing visions of inventiveness, utility, and improvement, as demonstrated by Denis Diderot's grandiose encyclopaedic project. Later, and above all through the work of Johann Beckmann, it underpinned the rise of technology as a scientific discipline (Hilaire-Pérez 2002, 137-43; Carnino and Hilaire-Pérez 2017, 18-28).

The references to Beckmann and *Technologie* bring us to our second point, namely that metalworking skills were linked to the manipulation of nature, or to several processes by which underground riches were transformed into metal products. Consequently, metalworking relied on investigations of the material world, through «observation» and «experimentation», activities that, in turn, generated information about «the structures of this world» (Bartels 2010, 73). The handling of metals, and changing perceptions of ways of working them, could thus inform us not only about manufacturing processes, but also about larger «material complexes», or «systems of knowledge that include materials, people, practices, and ideas» (Smith 2019b, 8). In employing such a perspective, we can also appreciate the multivalence of rudimentary objects, things that «were investigated using methods and concepts belonging to the scholarly world, but were never severed from the world of artisanal production, commercial circulation, and everyday consumption» (Klein and Spary 2010, 10).

It should be emphasised that the many levels and spheres of society for a long time were imagined as one divine, harmonious, and static whole. In early modern Sweden, where economic policy was formulated in line with cameralist ideas about resource utilisation and 'useful' industries, metalworking was seen as a key component of an inclusive *œconomia*, stretching down from the divine sphere, via the «common household» of the realm, to specific trades and individual households. Thus, the persistent trope of a prosperous householding regime in cameralist textbooks included a symbiosis between divine mineral resources, state regulation, and diligent work (Frängsmyr 1972; Rydén 2017). Similar perceptions of an all-embracing order, or, as put by Cynthia Koepp (2007, 97), that «the transformation of nature's matter by human labour and machines is simply an extension of God's original act of creating the world», can also be found in popularised books on arts and crafts.

In this text, we emphasise the «trafficking» between the manual working of metals and explanations of these manipulations. While eighteenth-century Sweden is placed at the centre, we duly realise, like Swedenborg, the need to insert our study within a larger context of movements and markets, our third feature. Iron and steel are good starting points, as these materials transcended the boundaries of individual economic domains, at the same time as they connected localities and work practices within Europe through trade, migration, and technical transmission (Harris 1998; Evans and Rydén 2007; Belhoste 2004). Thus, the «practical domain» of iron- and steelmaking was continuously shaped by «circulation, exchange, and appropriation»

(Klein and Spary 2010, 18), movements and activities that provide a basis for questioning ideas about «one-way communication processes» (Schilling and Vogel 2019, 11). In highlighting Swedish ironworks and steel furnaces, this study adds to previous research on the transfer of skills and technical know-how, while also demonstrating how these processes «implied plural and multicentered circulations» (Hilaire-Pérez and Verna 2006, 544). The following sections present empirical cases in a chronological order, and illustrate specific interactions, market relations, and movements. Taken together, they point to modified relations between manual skills, nature, and technology in the metal trades.

2. Manipulating the divine nature

Seventeenth-century Swedish metalworking was integrated in the European market, with growing amounts of copper and iron being exported from Swedish ports. The making of bar iron, benefitted from the immigration of Walloon workmen, saw a particular boost, and new ironworks (*bruk*) were founded close to ore deposits in the central Swedish mining region *Bergslagen* (Hildebrand 1992). This expansion also promoted steelmaking and arms production, areas linking state surveillance, commercial interests, and technical innovation (Sahlin 1931, 59-68; 73-86; Heckscher 1936, 500-6). The Great Northern War (1700-21) had a negative impact on the metal trades, but the making of arms also triggered an intensified activity at some places, like Vedevåg in *Bergslagen*, where production was directed towards fine wares. By the 1730s, when the British steel sector became a key market for Swedish bar iron, domestic steelmaking and iron manufacture were on the verge of a broader growth (Rönnow 1944, 80-154; Evans and Rydén 2007, 71-121).

In line with this development, people in the metal sector saw steelmaking as a prioritised area; «Steel ores» from Swedish *Stahlberg* could «easily [be] transformed into real steel» (Swedenborg 1923, 239). Two techniques, the making of crude and blister steel, dominated production, and continued to do so until the nineteenth century. In the former, steel was made by melting pig iron in finery forges, and then refined by welding and reheating. The resulting product was often referred to as welded steel (*garvstål*). The latter method was based upon the conversion of bar iron in steel furnaces, rendering a material that was covered in blisters, hence blister steel (*brännstål*). The making of crude and blister steel were introduced to Sweden at an early date. More lasting projects developed during the seventeenth century, depending on technical transfers from Central Europe and a well-supervised utilisation of the *Stahlberg*-resources (Sahlin 1931, 40-54). The «practical domain» of steelmaking became a subject of thorough description in reports and travelogues. The Vedevåg manufactory, producing both crude and blistered varieties, along with fine steel wares, offers good insights into the interplay of techniques, materials, and ideas about work, belonging to the same or different circulatory processes.[1]

The making of crude steel was initially scrutinised by Otto Dress, involved in the production at Vedevåg (Rönnow 1944, 38-45; Kromnow 1945). In 1687, he

[1] On the processes discussed in this section and the following, see also Jansson and Rydén 2003.

used his experiences to place metalworking within a broader frame of nature, technology, and movements. Regarding crude steel, he stressed the need for good materials, focusing on the supply of iron; after all, steel was «no particular metal, but only burnt iron». When aiming for a «hard, iron-free and strong steel», the rule was that the qualities of the pig iron were kept inside the material, so that «the steel becomes as the iron is». Consequently, one should look for a hard and «very tough» iron. From «soft iron» one could only expect a «brittle and weak» material. A trained eye could spot quality differences already during the initial processing in the blast furnace. Pig iron with an «ash gray» body was free of slag, indicating that it would melt «quickly» when «penetrated» by the steelmaker's fire. Iron that was instead «white as ice» retained internal impurities that made the steel fragile.[2]

Swedenborg (1923, 239) also noted that crude steel tended to «come close to the nature of iron». Like Dress, he emphasised that there were ways to learn about applicable iron sorts, a knowledge that was linked to bodily experiences of the *Stahlberg*; it was a question of observing and touching quality materials. Discussing the prominent Trollbo steelworks, he stressed that a key feature was the ore extracted from the Bispberg mine and refined into pig iron at Vikmanshyttan. This fine ore was recognised both by its «blackish» colour and by the fact that it was «not compact but composed of many small grains and crumbles between the fingers into a steel-like powder». When processed, it produced pig iron that was «very tough and all the way through consisting of sinewy fibres». The divine nature had, thus, been ordered so that underground riches were designed for unique uses, and the Bispberg ore was «particularly suited» for making steel (Swedenborg 1923, 232).

If nature, to contemporary observers, played a decisive role in the making of crude steel, the skills of those who worked to improve nature's good properties also became a subject of extensive interest. The «material complex» of crude steel production, relating to Pamela Smith's discussion, brought together a highly varied set of methods and practical experiences. The first step of the process, to melt the pig iron, should, according to Dress, take place in specially adapted hearths, where iron pieces were placed together with charcoal. The blast had to be strong to achieve an intense fire that purified the material, so that «all the iron in it is completely burned away». This «good art» of the steelmaker, Dress noted, was one «most difficult and significant science», since several interacting factors had to be considered, including the type and amount of charcoal and the placement and rhythm of the bellows. If any of the elements failed, and a high heat was not maintained, the result was a «bad and iron-blended steel, especially in the middle of the melted piece, where the slag usually remains».[3] Controlling the melting material itself was, however, always the most critical aspect of the smith's art, involving a comprehensive «sensorial intelligence», to use Bertucci's (2017, 159) term. In 1727, the Vedevåg supervisor Lars

[2] Uppsala universitetsbibliotek (UUB), *Handskriftssamlingen*, D.1620, Otto Dress «Beskrifning om Wapen och Gewähr, som Harnesk, Järn, och Kåppar Stycken, dem lätta och starka, kunna bekomma, Sampt om Lätta och Rätt skiutande Muaquete, Pijstole, Carabine, och studsare Pipor. Goda och Rena Låås der till, Om Ståhls Tillwärkningh, I synnerhet till Fiäddrar, lätta starka fijna Klingor, sampt om andre angelägne Krig Instrumenter af Järn och Stål, af Otto Dress», 28-32; 49. Rönnow 1944, 80.

[3] UUB, *Handskriftssamlingen*, D.1620, Dress, «Beskrifning», 33-8.

Harmens described how crude steel makers used a special method to separate the slag from the metal, so that the latter ended up «running dry» in the hearth. In doing so, they also «regularly powder the steel with ash, vitriol [and] alum», to enhance its quality, a procedure kept among the artisans like «a great arcana».[4] Swedenborg (1923, 234-35) added that such a process required cautious testing, which further highlights the importance of dexterity and experience. The moment when the iron was «in a proper liquid state, just about turning into steel», could be detected by manually inspecting the consistency of the mass as well as by observing the changing colour of the fire. Only after a second manual test, to determine if the melted lump had «hardened» to steel at the hearth's bottom, the piece was taken to be drawn out under the hammer.

The melting-hammering procedure was repeated until the desired quality had been obtained, and then the steel was forged out into squared bars. According to Swedenborg (1923, 236), this product was referred to as «melter's steel» or «forging steel». Despite such names, it was «not yet entirely composed of a real steel substance», and had to be refined by welding to become even and solid. The latter process improved during the first decades of the eighteenth century, in connection with growing ambitions to produce fine steel wares. When Dress commented on the Vedevåg steel, he noted that it lagged behind other places, and a reason was that the smiths did not employ a special forging hearth (chafery), but welded the steel in the same hearth as where the melting took place. The result was an impure material, lacking the qualities needed to make fine wares like cutleries.[5] Alterations took place, however, and Harmens described a more sophisticated procedure, with a forge equipped with two separate hearths. Crude bars were placed together in bundles, reheated, and drawn out under the hammer, and the anticipated quality decided the number of welding rounds; «blade steel» was welded four times, while the harder «spring steel» went through the same procedure eight times. During this process, the steel was continuously assessed; a good bar should, when broken and inspected, be «completely white» in the fracture, «like white-boiled silver», and not «spiny or streaky, with dark spots». Marking the number of welds on each bar, the smiths also provided the works' manufacturers with a quality guarantee.[6]

Refinement by welding, the «bundling» of crude bars, was another method by which skilled artisans manipulated the divine nature, making the material «throughout uniform» and adapting it for different uses. According to Swedenborg (1923, 238), it was a way to achieve «equal if not better quality», when compared to the renowned brands from places like Carinthia and Styria. Visiting England in the early 1720s, Henric Kalmeter observed a variety of metalworking practices in towns like London, Birmingham, and Sheffield, noticing the consumption of steel from Solingen and Styria. British steelmakers, like their Swedish colleagues, had also found ways to imitate Central European methods, creating brands such as «English Ger-

[4] Riksarkivet (RA), *Bergskollegium huvudarkivet*, E2i:3, Lars Harmens, «Berättelse om Wedwog och Qwarnbacka Jern och Stål Manufacturie, Upsatt år 1727», section 2.

[5] UUB, *Handskriftssamlingen*, D.1620, Dress, "Beskrifning", 48-49.

[6] RA, *Bergskollegium huvudarkivet*, E2i:3, Harmens, "Berättelse", section 2.

man Steel».[7] Such transfers of production techniques depended on workforce migration and the embodied dissemination of skills, clearly illustrated by the Swedish case. At Vedevåg, the steelmaking Hilphert-family descended from Thuringian immigrants. At the competing steelworks in Gravendal, the owners instead contracted an experienced Solingen-smith, Johan Wilhelm Piper, who arrived from Cologne in 1727 to supervise the making of welded steel «according to the Styrian manner».[8] Other places followed suite, and steelmakers were far from the only artisans arriving in Sweden. At Vedevåg, the Hilpherts provided steel to a growing number of foreign artisans, from France, England, Denmark, and Thuringia, many of whom were specialised in making fine steel wares like cutting tools.[9] The impact from these craftsmen requires more research, but it is not hard to imagine that «[t]he daily contact» between makers and users «benefitted the steel's quality» (Sahlin 1931, 61). Harmens noted that the foreign workers «at first did not know how to use our Swedish steel, but … when becoming accustomed to it, they admitted, that some Swedish steel is almost as good as the Styrian».[10]

Such a comment points to the importance of learning about steel by working it. Despite a variety of controls during production, the material only revealed its true nature when being further manipulated. In promoting his own invented steel – equal to «the best Styrian or any other European steel» – Dress noted that he, with «much diligence» and «the Lord's help», had contributed to the advancement of domestic steelmaking. Still, in order to determine the steel's quality, the material had to be «examined» by skilled craftsmen in Stockholm, including a Royal gunsmith and a watchmaker. Thus, a steelmaking entrepreneur like Dress was always dependent upon the manual dexterity and know-how of trained artisans.[11]

The efforts to improve welded crude steel paid off, with rising volumes entering the domestic market or being exported. In 1737, the new steel forge at Vedevåg, «large and complete» with two hearths and two water-powered hammers, employed three members of the Hilphert-family and two apprentices. They made blade and spring steel as well as «Styrian» varieties, a large part of which was sent to Stockholm and exported.[12] At the same time, however, the sector faced problems, one of which was the dearness of production. Harmens noted that 115 kilograms of pig iron and 2100 litres of charcoal were needed to make just one *centner* (ca 42,5 kilograms) of spring steel.[13] Secondly, notwithstanding the attempts to refine the material through welding, crude varieties were always ambiguous. The quality of a single batch could be highly variable, with some bars being pure, others remained tainted by iron-strands or impurities. For this reason, makers at Vedevåg preferred another steel, one «freed from the coarse sulphur by firing». This «blistered» steel

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[7] Kungliga biblioteket (KB), *Handskriftssamlingen*, M.249, «Henrik Kalmeters resa», vol. III, 75-78; 732-38; 751-59. See also Evans and Rydén 2007, 135-40.

[8] RA, *Bergskollegium huvudarkivet*, E4:178, 1155; Sahlin 1931, 164; 186.

[9] RA, *Bergskollegium huvudarkivet*, E2i:3, Harmens, «Berättelse», sections 2 and 3.

[10] RA, *Bergskollegium huvudarkivet*, E2i:3, Harmens, «Berättelse», section 2.

[11] UUB, *Handskriftssamlingen*, D.1620, Dress, «Beskrifning», Preface.

[12] RA, *Frihetstidens utskottshandlingar*, R. 2684, No. 8.

[13] RA, *Bergskollegium huvudarkivet*, E2i:3, Harmens, «Berättelse», section 2.

could more easily be adapted by the manufacturing smiths, «by welding and hardening», and «applied for whatever type of work they want».[14] While Dress stated that «steel made from burnt bar iron in furnaces» always was inferior to crude sorts,[15] commentators in the 1720s and 1730s tended to agree with Harmens's observation, and held blister steel in higher esteem.

A steel furnace was erected at Vedevåg in 1721, built by bricks made from «French clay» to become «stronger and more fireproof». The cementation was carried out according to a traditional – «German» – method, using charcoal. About 2,5 tons of bar iron were packed together with «coal dust, French clay and ash», and the furnace was closed and ignited. It took about three weeks before the heated iron had transformed into steel, some of which was «unevenly burnt» and had to be «knocked off» before being handed over to the manufacturing smiths.[16] Similar projects took place in the following decade, in some cases relying on English technology. These ventures show how the making of blister steel was as dependent on a generous nature as the crude steel production. While in England, Kalmeter observed how high-quality bars, mainly «Oreground» iron from *bruk* in Uppland, were «the most coveted varieties». In Stourbridge, these bars were put into «pans, or chests», together with coal, and «converted» to steel in a week. The temperature was raised gradually, only to be lowered during the final phase, during which special care was taken so that «the iron does not melt or become fluid». The works-owner could also, contrary to crude steel production, maintain control over the cementation process, by inspecting so-called «test bars» to see if the iron was fully «converted». In Kalmeter's view, however, it was the use of coal and Swedish iron that gave the «merits of English steel».[17] This combination of raw materials was also in focus at the Tyresö manufactory, outside Stockholm, where attempts were made during the mid-1730s to get to grips with the «faulty internal quality» and «weak matter» of Swedish crude steel. The English-born entrepreneur John Peter Smith succeeded, after having persuaded his steel-making brother William to join him, to set up a coal-fired furnace, which was intended to provide metalworking artisans with «steel prepared according to the English manner».[18]

As with crude steel, the efforts to improve blister steel production also hinged on embodied know-how. At Vedevåg, expert professionals were brought in from the outside. «[S]ince only two furnaces [batches] have been made per year for the needs of the works», Harmens noted, the steelmaker was «paid for each furnace, including expenses for travelling from and back to Stockholm» and, moreover, provided with «two assistants».[19] William Smith at Tyresö moved longer distances to put the steel business in motion, as he made a «difficult, dangerous, and expensive journey» back to his native country, to procure coal, building materials, and tools. While in England, he also recruited several craftsmen, needed «for the continua-

[14] RA, *Bergskollegium huvudarkivet*, E2i:3, Harmens, «Berättelse», section 2.

[15] UUB, *Handskriftssamlingen*, D.1620, Dress, «Beskrifning», 28-30.

[16] RA, *Bergskollegium huvudarkivet*, E2i:3, Harmens, «Berättelse», section 2.

[17] KB, *Handskriftssamlingen*, M.249, «Henrik Kalmeters resa», vol. III, 732-38.

[18] RA, *Bergskollegium huvudarkivet*, E4:178, 72-75; E4:181, 114-15.

[19] RA, *Bergskollegium huvudarkivet*, E2i:3, Harmens, «Berättelse», section 2.

tion» of the English-style furnace, including steelmakers, cutlers, and file makers.[20] These cases illustrate how workforce circulation was a key in shaping a «material complex» during the early decades of the eighteenth century, one that also incorporated transports and uses of raw materials and the adaptation of building techniques. From mid-century, blister steel production rose on the agendas of state experts and entrepreneurs, as it was formed by changing ideas about work and markets as well as by movements of men, matter, and technical knowledge.

For Dress, Harmens, and Swedenborg, it was clear that God had equipped Sweden with particularly good prerequisites for metalworking. The iron trade generated valuable incomes for the state as well as for private groups, and it was therefore seen as a crucial aspect of the domestic «householding» order. To benefit from these resources, however, Swedish makers needed to improve their capacities to refine the iron, and in this context, steelmaking came to occupy an important role, as a link between iron production and metalware manufacture. While the three authors were familiar with the «practical domain» of iron and steel – Dress managed to promote a 'self-invented' steel variety and Harmens supervised the production at Vedevåg – they all lacked the embodied know-how required to bring about lasting improvements in the realm of everyday work. The possible ways of making and working steel remained 'unseen' in the sphere of craftsmanship; methods and skills could be observed and described, but were still largely inaccessible to outsiders. This gradually changed over the following decades, as some *savants* not only took over the task of describing what happened in forges and furnaces, but also engaged in transforming the divine nature themselves.

3. Hybrid experts and the quest for improvements

The development that begun in the 1710s and 1720s, at places like Vedevåg, intensified at mid-century, as new markets opened and large, state-catered, investments were made in the domestic manufacturing sector. Again, outside impressions were crucial. Travelling in the German lands, Swedish officials observed crude steel production, with an array of techniques and work practices that played an important part in a larger system of trade and consumption. In 1758, Reinhold Angerstein described various steel brands made in the Bergishes Land, many of which were exported to Britain and the Low Countries.[21] His colleague Sven Rinman, who travelled in the same region a decade earlier, reported about the ways in which pig iron was turned into crude steel and adapted for special uses through sorting and welding, activities highlighted as the «foremost science of the steelmaker».[22] From Sweden, the state supervisor for fine metal manufacture, Samuel Schröder, de-

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[20] RA, *Bergskollegium huvudarkivet*, E4:178, 84; E4:181, 114-15; E4:183, 872-73.

[21] RA, *Bergskollegium huvudarkivet*, E3:27, Reinhold Rüdker Angerstein, «Om Järnwärcken Bägge Sidor Rhenströmmen, Ifrån Bodensee i Sveitz till Coblentz, Af Reinhold Angerstein, utgifwen År 1758», 93-97.

[22] Kungl. Tekniska Högskolans bibliotek (KTHB), *Manuskriptsamling, Bergsskolans biblioteks manuskript*, K12, Sven Rinman «Utdrag af Beskrifningarne öfwer Någre Utländske Jern och Stål Fabriqwer besedde År 1747, af Swen Rinman, Första stycket», 17-53.

described a similar structure. In 1756, he noted that eleven types of welded crude steel from Graninge and Sollefteå were sold in Stockholm. Among them were varieties previously described by Rinman, made by «Solingen-smiths».[23]

This diversification was important, as it provided a foundation for the attempts to elevate domestic manufacture (Jansson 2017, 72-4; 127-38; 220-4). At the same time, the state officials were aware of the risks of building such an expansion solely on the unpredictable nature of crude steel, especially when competing with British makers. A special attention was paid to Oreground iron. Reporting from Tyresö, in 1744, Samuel Linder stated that other bars had been «completely useless» when converted in the English-style furnace.[24] Schröder stressed that most of the Oreground iron was «sold to England», where steelmakers already had proven that «these sorts make the best blister steel». Thus, Sweden, with only «a few furnaces», had to follow the English example (Schröderstierna 1925, I, 53). However, he did not have the technical know-how to lead such an enterprise. This instead became a task for his colleagues, Sven Rinman and Bengt Qvist. Zooming in on a «test furnace» in Vissboda and a steelworks in Stockholm reveals how the making of blister steel was adapted to Swedish 'nature'. These practices illuminate the shaping of hybrid expertise in the intersection of science, state making, and craftwork, or, relating to Chris Evans and Alun Withey's (2012, 555) discussion, how «new types of "enlightened" activity» became «stimulants to technological innovation».

Rinman embodies the idea of a «hybrid» individual. He was educated at Uppsala University, before entering a junior position at *Bergskollegium*. After several study tours, he rose through the mining administration. From an early age, he had combined academic studies with craftwork, and acquired experiences from training with metalworking artisans.[25] This inclusive approach was seen when Rinman, as state supervisor for the coarse manufacture from 1760, involved himself 'hands-on' in working activities, notably so in the making of blister steel. A key event, one that also made a significant imprint in Rinman's authorship, was the encounter with Johan Ludvig Robsahm, and the attempts to construct a «Swedish» firewood-furnace at the Vissboda *bruk* in *Bergslagen* (Sahlin 1931, 90-3; Boëthius 1955, 48-62). Their task was to transform Oreground iron into high-quality steel, with the use of fuels other than imported coal or charcoal. Rinman never visited England, but Robsahm had seen coal-fired furnaces during his foreign study tour. He was willing to make further investigations at his own *bruk*, with Rinman becoming his companion (Nordenvall 1998-2000, 252). In 1766, Rinman visited Vissboda, to partake in «trials for the improvement of steelmaking», and «examine what benefits that can be expected from such new cementation methods».[26]

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[23] KB, *Handskriftssamlingen*, X.283, Samuel Schröder, «Dagbok rörande Directeurs-Sysslan öfver Jern- Stål- och Metall-Fabrikerne i Riket af S. Schröder», vol. I, 1756, 105; Sahlin 1931, 58-9; 162-3.

[24] RA, *Manufakturkontoret huvudarkivet*, D5:180, Samuel Linder, «Beskrifning öfwer en Engelsk Stålugns byggnad samt om processen af sielfwa Bränningen el: Stålets beredan - ingifwen d. 1 Junij 1744».

[25] UUB, *Handskriftssamlingen*, X.286, Sven Rinman, «Lefverne och Meriter, 1789». See also Nisser 1998-2000, 212-19.

[26] Tekniska museets arkiv (TMA), *Sven Rinmans arkiv*, S-E:11b, Sven Rinman, letter to *Bergskollegium*, 1766-10-16.

During this 'open-air'-experiment, Rinman made systematic observations. Four types of bar iron, three of which were Oreground brands, were packed in the two chests together with a special «additive», composed by «the same substances» as in England. Robsahm then began the process «with a slow firing». Wood was added, «every half or quarter of an hour», increasing the heat until the point when «test bars» were taken out and examined. After the furnace was cooled down, Rinman noted that most of the bars were properly «converted into steel». This was confirmed by additional tests, made by «breaking and forging» some of the bars. They proved to be «pretty strong and less brittle than the usual Swedish blister steel». Importantly, the steel was «as good as that made in coal-fire».[27]

Rinman saw several «advantages» with the method. It was less resource intensive and therefore less costly, especially if compared to the charcoal-based production. The process also demanded «less experience and art during the firing and the maintenance of the furnace». Since the 'new' fuel gave a «more even heat», and thus a more evenly burnt steel, one did not have to rely on «a trained and diligent master». During the tests, Robsahm oversaw the entire cementation, assisted by one «helper».[28] Compared to crude steel production, Rinman added, blister steel making in «Swedish» furnaces contributed to even greater savings in terms of human resources, not only by reducing the direct labour costs, but also by avoiding the «difficulty of getting skilled welding smiths … recruited from Germany».[29] Finally, in terms of dissemination, Rinman envisioned that the «test furnace» at Vissboda could inspire similar facilities elsewhere. The new technology was, thus, not site-bound, but could serve «the benefit and enlightenment» of others, a fact that the mining official took advantage of, when leading the work of replacing coal-fired furnaces with firewood-versions in Uppland during the 1760s.[30]

Rinman took an active role in implementing the new technology, but it was a gradual process dependent upon skilled workmen. Rinman elaborated the design for a charcoal-fired furnace at Åkerby *bruk* in 1763, but it was masons and a master builder who erected the construction. An experienced steelmaker from Nykvarns *bruk*, was hired to make the first batch of steel, but also to train an apprentice, Carl Boivie, who later took charge of production. In 1768, when designing a new firewood furnace, Rinman was also responsible for the cementation, selecting fules and iron bars as well as overseeing the firing process. It was only during the second batch that Boivie retained full responsibility of making steel at Åkerby.[31]

With the problems of furnace construction and fuelling being partially resolved, the challenge of refining the blistered bars still remained; blister steel was, although it was often purer than crude varieties, still «a very imperfect material» (Evans and Rydén 2007, 137). Welding offered a solution, but from the 1760s, growing attention was paid to another technique: crucible steel. This area of production involved

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[27] TMA, *Sven Rinmans arkiv*, S-E:11b, Rinman, letter to *Bergskollegium*, 1766-10-16.

[28] TMA, *Sven Rinmans arkiv*, S-E:11b, Rinman, letter to *Bergskollegium*, 1766-10-16.

[29] TMA, *Sven Rinmans arkiv*, S-K:8, 71-3, Sven Rinman, essay on steelmaking.

[30] TMA, *Sven Rinmans arkiv*, S-E:11b, Rinman, letter to *Bergskollegium*, 1766-10-16; Sahlin 1931, 90-3.

[31] Leufsta bruksarkiv, *Leufstaarkivet*, vol. 246, 290, 292, and 297-9.

Rinman's former assistant, Bengt Qvist, who, during a tour to England in 1766 and 1767, made observations of ways in which blister steel was brought to its «highest level» through «re-melting» in specially-made crucibles.[32] Back in Sweden, he initiated the construction of a crucible steel works in Stockholm, a project that, even though it ultimately failed, has been highlighted as a pioneering technical achievement (Boëthius 1955, 76-80).

In Qvist's view, the re-melting of blister steel required a sound knowledge about the materials being processed. He stressed «the care required for the steel to retain its previous elements while dissolving in the fire», and later added that «a more evenly burnt, iron-free, and hard blister steel renders the finest, most compact, and hardest crucible steel», so that it kept its «natural qualities». Still, handling this manipulation was more a matter of finding technical solutions than of relying on the practical experience of craftsmen.[33] Reporting in 1769, he dealt in detail with the erection of air furnaces and the correct ways of putting in, heating up, and casting the steel, but said less about the proficiencies required to handle the process. A steelworks with six furnaces needed just two workers, hired to perform rudimentary chores such as inserting and removing the crucibles.[34] Thus, the making of crucible steel was, according to Qvist, an art almost entirely depending on the technical expertise of men like himself. Another English traveller with an interest in crucible steel, Gustaf Broling, later made similar conclusions, detailing that the «main circumstances» of production were a set of technical and material components – proper furnaces, good crucibles, and a «powerful» fuel – together with the use of high-quality blister steel (Broling 1817, 24-53).

Paradoxically, expert *savants* like Broling – who also experimented with the making of crucible steel – and Qvist had to rely on artisanal dexterity in the processing and, not least, the examining of steel. Broling stressed how the hardening process, a decisive task when making delicate items such as razors, depended on a vast «experience» in visually assessing the correct degree of heat as well as on proper manual skills gained though the «extensive handling» of the material (Broling 1817, 74). When Qvist, in 1787, after several unsuccessful attempts, presented the «improvements» made at his steelworks, he exposed similar dependencies. Parts of the output had been distributed to investigate potential markets, and among the recipients were highly reputed manufacturers, such as the Royal Swedish watchmaker Eric Lindgren and the Parisian cutler Jean-Jacques Perret. The latter responded to Qvist that he had made «different tests» with the steel, and queried if it was «made without having passed through the state of iron».[35] In his *Mémoire sur l'acier*, Perret (1779, 6-7) had distinguished such «natural melted steel» (*acier fondu naturel*) from

[32] KTHB, *Manuskriptsamling, Bergsskolans biblioteks manuskript*, E12, no. 5, Bengt Qvist Andersson, «Beskrifning om Gjutståls beredningen».

[33] KTHB, *Manuskriptsamling, Bergsskolans biblioteks manuskript*, E12, no. 5, Qvist, «Beskrifning om Gjutståls beredningen»; TMA, *Sven Rinmans arkiv*, S-K:2, Bengt Qvist Andersson, memo to *Jernkontoret*, 1787-04-26.

[34] KTHB, *Manuskriptsamling, Bergsskolans biblioteks manuskript*, E12, no. 5, Qvist, «Beskrifning om Gjutståls beredningen».

[35] TMA, *Sven Rinmans arkiv*, S-K:2, Jean-Jacques Perret, letter to Bengt Qvist, 1783-08-01.

«artificial» blister steel, while also admitting that the «secret» British crucible steel was «the finest» variety in trade. Later writing to Qvist, he recognised the high quality of the Swedish-made imitation, and noted that «no one has been as close as you, to access its English foundation». Moreover, as a gift, Perret had made six razors from the tested materials, which were sent back to Stockholm.[36] Qvist later noted that these were «quite good, although some of them were too hard». Unfortunately, Perret died before a second consignment arrived from Sweden – including samples of «acier fondu naturel» – and Qvist had to make do with shaving himself with his own steel.[37]

In a concrete way, these examples illustrate how the manual handling of metals played a crucial role in producing knowledge, but it also shows how the work of hybrid experts in Sweden was intimately entangled with a complex set of makings, movements, and market contacts. As noted, such practical experiences also made an imprint on the *savants'* writings. Rinman and Qvist were not only practical men, but also writers about metalworking. If Swedenborg was our starting point to the process of treating metals within a cameralist discourse, Rinman should be placed at its tail end. He published three major publications in the last two decades of his long service to the Swedish mining administration. In 1772 appeared his *Anledningar til kunskap om den gröfre jern- och stålförädlingen och des förbättrande* and ten years later came *Försök til järnets historia*. In 1788-89, he crowned his achievement with a two-volume encyclopaedia, *Bergwerks Lexicon*. There is a clear development between these publications, with the first being a hands-on book on metal processing, while the second took a more scientific approach, compiling many experiments undertaken by Rinman. The encyclopaedia was both practical and scientific (Rinman 1772; 1782; 1788-89; Holmberg, *forthcoming* [2023]).

The beginning to Rinman's *Anledningar* was the concept of *œconomia*, and its two parts, work and nature. The crucial point was that humans manipulated nature when making goods, but the processed materials always kept some of their properties, and thus remained more or less the same, so that «art could do bits, but nature the most». Even work was a part of nature, as artisans received their skills by imitating each other, but, in the end, these talents were infused to workers through divine intervention. Dealing with skills, Rinman used concepts that stemmed from connotations to the hand, such as *handalag* (manual skills) and *hand-arbete* (manual work), but also referred to «art» as something aiming to imitate the creation. All human making were, thus, embedded in a divine and static structure, also encapsulating markets and consumption. When Rinman discussed the marketing of goods, stating that it required «all possible householding», he had a zero-sum-game in mind. If Sweden could sell steel on the European market, other makers would lose out. He talked about improving Swedish metalworking and its *œconomia*, but what he had in mind was to adjust the Swedish trade in accordance to the best practice of «more trained nations» (Rinman 1772, 5; 12; 55; 252; 256).

Qvist was not as prolific as a writer, but his two speeches in front of the Swedish Academy of Sciences were published, and the first one is worth highlighting.

[36] TMA, *Sven Rinmans arkiv*, S-K:2, Perret, letter to Qvist, 1783-08-01.

[37] TMA, *Sven Rinmans arkiv*, S-K:2, Qvist, memo to *Jernkontoret*, 1787-04-26.

He followed the same path as Rinman, but due to its compact format, he presented his ideas in a more stringent way; Qvist's speech became a kind of swansong for Swedish cameralism. His beginning was to put «more working hands» to utilise Sweden's underground «treasury», and to do that «at foreigners' expense». Sweden should make bar iron for foreign markets, but also develop steelmaking and the metal trades to expand exportation further (Qvist 1776, 3-4). As Qvist delivered his speech in 1776, it is difficult not to make comparisons with Adam Smith's *The Wealth of Nations*. Even if Qvist belonged to the cameralist 'camp' there were similarities, with an analytical link drawn between markets and production, and from there to what Rinman called a «general improvement». The latter concept, however, hardly contained what we today see as economic growth or a changing society. Neither Qvist nor Smith imagined any dramatic transformations within the sphere of production. To Smith, it was all about the division of labour, and to this, the Swedish writers added the importance of understanding the actual practices and processes of work, notably so by drawing on experiences from having interacted with artisans and involved themselves in the everyday manipulation of nature. Neither of them dwelled on ideas of technological change, and they could not do so, as the concept was introduced into the scientific discourse one year later. In 1777, Johann Beckmann published his *Anleitung zur Technologie*, but to him as well technology was a science of how to make things «in systematic order», and could almost be equated with division of labour. Rinman similarly defined «technology» as «the knowledge of how to prepare raw materials from the three natural kingdoms and to make use of them for œconomy, factories, arts and crafts» (Beckmann 1777; Sebestik 1983, 31; Rinman 1789, 969). While hybrid experts like Rinman and Qvist had entered the world of artisanal work in a more active way, it became the task of others to contribute additional layers to the understanding of work and nature, placing human makings within a framework of changing markets and technical progress.

4. Seeing the previously unseen

The dawn of the eighteenth century became a watershed for Swedish metalworking, and the new century saw an altered relationship between «*episteme*, *praxis*, and *technē*», but with the market in a more prominent position. There were different causes behind this rupture, such as the Napoleonic wars, but a more penetrating force was the dramatic development in Britain. The British market was the main outlet for Swedish bar iron and the wars hampered Swedish export, but new ways of making metals gradually grew into an even greater obstacle. The traditional narrative of this development is one of a British industrial revolution, leaving the rest of the world trailing; Swedish ironmaking faced the full power of coke smelting, steam engines, and puddling, and lost its dominant position (Harris 1988). In recent years, a more nuanced approach has been elaborated, with technological development being inserted in a social setting, embracing division of labour, tariff regimes, and market-related issues. Having said that, it is beyond doubt that British ironmaking was transformed from mid-eighteenth century, with small furnaces and forges being replaced by large ironworks. In places like Merthyr Tydfil, thousands of workers produced more iron than the entire Swedish iron trade (Evans and Rydén 2005; Jansson and Rydén 2022).

Tony Wrigley (1988; 2010) has seen this development as one from «an organic economy» into «the mineral based energy economy», but with an «advanced organic economy» in between. With the latter, he meant a society with a foundation based upon organic energy sources, but with division of labour, intensified labour regimes, and a growing coal consumption. Qvist and Rinman belonged to this «advanced» stage. During his English tour in the 1760s, Qvist saw many ironmaking sites, and his report points to a society slowly moving out of the organic economy.[38] He noted processes where coal had replaced charcoal, as in roasting and reheating blooms, and described coke smelting and attempts with «bar iron making in air furnaces». However, these remarks were noted in passing and not heralded as something radically new. Instead, they were described as different ways of making iron, neither better nor worse compared to ironmaking in Sweden. In fact, he always placed Swedish charcoal-made iron, with its higher quality, ahead of British iron. In 1776, he remained in tune with the traditional matrix, in which *technē* was subordinated to the praxis of doing, and where knowledge about this praxis remained in the domain of artisanal work. Change was not on the horizon.[39]

Qvist's report was the end of a tradition, from two angles. He was the last predecessor of Swedish ironmaking going to Britain for three decades, but more importantly, he was the last to portray English furnaces and forges in the language of cameralism. In his view, Sweden and Britain were parts of an integrated system, regulated as a zero-sum game. What Sweden lost in the British market had to be regained by an «Intrusive spirit» (Qvist 1776, 4-9; 22; 27-28). Eric Thomas Svedenstierna, who left Sweden at the turn of the century, would produce an entirely different description. After studying chemistry and mineralogy in Paris, he arrived in London in 1803, and set out for a journey to British metalworking sites, including the gigantic works at Merthyr Tydfil. His narrative includes the first Swedish descriptions of the mineral-based energy economy, with coke smelting, puddling, rolling, and steam engines (Svedenstierna 1804).

Svedenstierna was educated at Uppsala University, and entered a career in the mining administration at *Jernkontoret*, before being given the important task of supervising people employed at blast furnaces. This assignment later came to include bar iron making as well, and, from early on, he was involved in experiments to know more about the properties of both iron and steel. Although he was not an entrepreneur like Qvist, or involved in the practical side of the trade as Rinman, Svedenstierna was an «unmistakable talent [with] wide-reaching scientific and general interests, technical brilliance and fruitful ideas», and thus a perfect candidate for the task of observing British ironmaking (Boëthius 1955, 4). After his return, he became a pioneer in editing volumes on ironmaking. His intellectual beginning was similar to the one ruling at mid-eighteenth century, with a static worldview, but the journey to Britain changed all that. The market remained crucial, and Svedenstierna

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[38] RA, *Jernkontorets arkiv, Fullmäktiges arkiv*, FIIa:20, Benct Qvist Andersson, «Anmärkningar uti Hvarjehanda förefallande Ämnen samlade på resan i England åren 1766 och 1767».

[39] RA, *Jernkontorets arkiv, Fullmäktiges arkiv*, FIIa:20, Qvist Andersson, «Anmärkningar».

was aware that Swedish iron producers lost ground, balancing «on the outer edge […] undermined and weakened by foreign industry» (Svedenstierna 1810, 47, 52), after «a surprising development of England's Political, Industrial and Trade System».[40] In order to scrutinise the Swedish dependency on Britain, he developed a model centred on industry, market, science, and progress (Svedenstierna 1807a). A precondition for this analysis was the deconstruction of the previously dominating concept of trade, as an amalgam of production, commerce, and consumption. Svedenstierna began to see them as independent entities, and made a distinction between «construction methods and labour processes». He abandoned Beckman's definition of *Technologie*, as «the knowledge of handicrafts», for an analysis of technological development with a potential to change society. Physical artefacts like puddling furnaces and steam engines were placed at the centre, while labour was pushed to the background. Technology, as understood more in the modern meaning of the term, became Svedenstiernas main theme.

This replacement of labour by technology was complemented by the introduction of a novel concept, that of industry. The word existed in eighteenth-century Swedish, meaning to be diligent, but with Svedenstierna it got a modern connotation of a workshop-based production, pointing especially at British ironmaking (*Svenska Akademiens ordbok*, «industry» [https://www.saob.se/artikel/?seek=industry, 2021-08-10]). With this discursive change, he altered the link between the market and production, to one where the market was attached to one specific type of production, that of industrial production (Svedenstierna 1807a; 1813, 60; 62). If the *praxis* of skilled workers had been at the forefront before, the internal balance of production had swung towards *technē* and *episteme*. The key features were machine makers and their machinery, and technology became the solution to a successful iron production. According to Svedenstierna, «English ironmaking can count its beginning» from the introduction of James Watt's steam engine, and the «mineral-based energy economy» had opened «prospects for a future with almost endless production» (Svedenstierna 1807a; 1807b, 27; 1813, 14; 16).

Svedenstierna thus left the static world of cameralism behind him, for one with change and progress. If British entrepreneurs had escaped the shackles of the organic economy, the same would be possible for Swedish ironmasters; the English development became not only a threat, but also a path to follow. Technology could be copied, and Svedenstierna stressed that one should have faith in development; it was necessary to «tirelessly [follow] the direction of the age and hence the improvements arising» (Svedenstierna 1807a). Gustaf Broling concurred: England was «the most industrial country», and he wanted Sweden to follow the British path (*Svenska Akademiens ordbok*, «industriell» , [https://www.saob.se/artikel/?seek=industriell, 2021-08-10]).

In 1810, Svedenstierna outlined a future for Swedish ironmaking. Sweden had been blessed with «rich deposits of iron ore», and he told the story of how ironmaking had developed towards a progressive and enlightened present. During the eighteenth century, it reached a «greater height than ever before». The causes were a

[40] RA, *Jernkontorets arkiv, Fullmäktiges arkiv*, FIIIa, bunt 39, Eric Thomas Svedenstierna, «Allmän öfversikta af de sedan år 1805 i Svenska Jernhandteringen gjorda förbättringar».

«corporative spirit» among everybody involved in the trade, together with the «competition» on the British market. New production methods grew in importance, the «happy inventions by known *Mechanici*», and Rinman was seen a key actor in this process. However, this development reached an end with the turn of the century, as the coal technology altered the frame for Swedish producers. It was the effects of rising British output, caused by coke-fired blast furnaces, puddling, and rolling mills powered by «Mr. WATT'S improved Steam Engine», that placed Swedish ironmasters on that «outer edge». This did not mean that Svedenstierna lost the faith for the future, as «the improvement of the sciences and their application; common enlightenment and connected consideration, industriousness and thrift» meant that one only had to follow «the direction of the age», and «new ways» to markets would open. (Svedenstierna 1810, 37, 41-5, 52-5). However, it was not with Svedenstierna that this prognosis was fulfilled. The situation got worse towards the end of the wars, with a slumping production and export, and it became obvious that British industry was the main cause behind the problems; it was during the wars that puddling and rolling made the breakthrough. Only Oreground iron had a secure position on the British market, supplying Sheffield steelmakers with coveted bars.

Gustaf Ekman, a «hybrid figure» from a later generation, was the one to lead Sweden towards a brighter future, but the process was more complicated than first anticipated. Puddling was tried at a few Swedish works, but due to the lack of mineral coal, this proved to be a wrong turn. Ekman wrote that it «was difficult to directly apply English ironmaking in Sweden», but a better information about what happened in Britain would improve the knowledge «about the qualities of iron», and that in turn would make it easier to «compete». Quality was another obstacle, as puddling often gave inferior iron.[41] This proved to be Ekman's approach, of trying to combine an imitation of British ironmaking with an iron of high quality. In 1828, he travelled to Britain for the first time, visiting Merthyr Tydfil as well as smaller ironworks, and after his return, he was put in charge of Lesjöfors *bruk*, in *Bergslagen*, which became his testing place for novel technology.

Ekman discovered small pockets of charcoal-made iron in South Wales and Lancashire, referring to it as the «English Walloon process», a technology with few resemblances to Swedish forges, but with charcoal usage as a crucial link. The British hearths were different, and inserted in a structure similar to the one at Merthyr Tydfil. Pig iron arrived from coke furnaces, while the blooms were taken to coke-fired welding furnaces, and the bars were shaped in rolling mills. Steam engines powered mills and hammers, and what Ekman saw was an industrial form of charcoal-made iron (*Jernkontorets Annaler* 1836, 170-250). When he returned to Sweden, Ekman set out to emulate what he had seen. The first step was to develop new hearths, but the main obstacle was welding. British coal-fired furnaces generated more heat than was possible with charcoal, but in the 1840s, Ekman developed a gas-generator that gave a more intense heat. The new technology, renamed to «Lancashire forging», began to spread among Swedish ironworks. Ekman also installed new hammers and blowing machines, seen in Britain, along with equipment to supply hearths and furnaces with pre-heated air.

[41] RA, *Jernkontorets arkiv, Fullmäktiges arkiv*, FIIa:12, «Directeur G. Ekmans Utländska Resa» 1833.

Others followed Ekman's trail, equipped with Svedenstierna's ideas, with the market tied to industry, and with production centred on *technē* and not on artisanal skills. They saw themselves as masters of technology. Their task was to observe British technology and bring back to Sweden what was possible to implement (Harris 1998). Teofron Munktell set out in a typical way. From a small ironworks in Leeds, he stressed that his «attention was principally drawn to [it] as its size corresponds to what [Swedish] ironmasters can erect». In a similar vein, J.S. Bagge noted that the purpose of his journey was to «acquire closer acquaintance [with] the proper machine making», and added that it was with «new inventions and improvements [that] each manufacturer took one step ahead of his competitors».[42]

With observations like these, and a gradual implementation of new technologies, Swedish bar iron production expanded from the end of the Napoleonic wars, but the breakthrough took place with the introduction of Lancashire forging. British steelmaking was once again the main outlet for Swedish iron. Oreground iron remained the most coveted bars, but as the production of blister and crucible steel rose from mid-nineteenth century, the demand for new iron brands increased. Lancashire iron filled a void, although it always ranked as inferior to Oreground iron. French metallurgist Frédéric Le Play noted that bars from the prominent *bruk* in Uppland were purchased for prices twice as high as bars from other places (Attman 1986, 14-22; Barraclough 1987, 246-259; Rydén 1998; Le Play 1845).

A new worldview reigned within Swedish ironmaking from the early nineteenth century, with the British developments seen as both a threat and a possibility. The new generation of «hybrid figures» wanted to copy small ironworks and new machinery, with Ekman as the paramount example. He strived to combine English technology, with new hearths, welding furnaces, and blowing machines, with a continuous reliance on charcoal. For Svedenstierna, this was to «tirelessly [follow] the direction of the age», and technology was the solution. Still, a man like Ekman was also aware of the importance of skilled workers for the success of British industry. In 1833, he noted that one of the causes for the English superiority was the «common spread enlightenment among the working classes, especially the practical sciences», and he added that the development of puddling initially was hampered by the puddlers «being untrained in this profession». It was only later when «enough used workers had been created», with a «required level of skills», that the new process could spread.[43] The labour question returned as the novel technology was implemented at Swedish ironworks. Ekman was aware of the importance of skilled workers, when he elaborated the new refining hearths. The forgemen were not used to a faster tempo resulting from higher temperatures, nor did they know the proper «work method» (*Jernkontorets Annaler* 1830, 291; 328; 331-32). Other writers likewise became painfully aware of the need for skilled artisans when introducing novel technology, but it was Ekman who led the way. He remarked that Swedish forgemen had «difficulties in adapting the necessary vivacity in their motions needed for this method», and three years later, he lamented the problems with «the worker's training» (*Jernkontorets Annaler* 1832, 172; 1834, 69).

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[42] RA, *Jernkontorets Arkiv, Fullmäktiges Arkiv*, FIIa: 8-17.

[43] Jernkontorets Arkiv, Fullmäktiges Arkiv, FIIa) 12, Riksarkivet; *Jernkontorets Annaler* 1831, 531.

Some opposing voices could be heard, as when one writer noted that the quality of the iron would in the future «depend less on the forgeman's skill, industriousness and consideration» (*Jernkontorets Annaler* 1832, 105-106). Another commentator similarly stressed that the introduction of new welding furnaces could be a way of controlling artisans' work. The high temperature reached in the furnaces gave «a technical advantage», and, in so doing, these devices acted as «incorruptible controllers» to the forgemen's work at the refining hearths (*Jernkontorets Annaler* 1847, 126). The comments from Ekman show, however, an awareness of the reliance on good workers throughout the first half of the nineteenth century; the introduction of British novelties did not make artisanal skills redundant.

5. Concluding remarks

This study has highlighted the interplay between manual practices, nature, and technology within the early modern knowledge economy, using the making of iron and steel in Sweden as our main example, although integrated in a wider context of enlightenment Europe. Our analysis provides insights into the interactions between material makings and perceptions of work in a society that was still, albeit to a gradually lesser extent, dominated by ideas of a divine order encapsulating both humans and nature. With such an approach, we add to recent discussions about industrial and intellectual developments in the early modern period, elaborating on the relationship between «hand» and «mind», practice and theory, and exploring the circulation of skills, ideas, and objects across geographical distances and social divides. In these debates, the metal trades have a pronounced position, but seldom from the viewpoint of rudimentary objects such as iron and steel bars. Our study highlights the making, testing, and consuming of these bulky metal things, activities that often brought together skilled artisans and state-employed «hybrid experts».

The analysis builds on three empirical cases, all illustrating the centrality of craft skills and the manipulation of nature, but at the same time stressing the wider spatial context, with movements of people and technology, as well as changing markets. We have shown how, in the early eighteenth century, the making of both crude and blister steel relied on a sound knowledge of nature and diligent manual labour. In crude steel making, the material foundation was the rich resources of the Swedish *Stahlberg*, and in blister steel production, it was all about the high quality of Oreground iron, together with the selection of appropriate fuels. The process of transforming nature into iron and steel was in the hands of skilled craftsmen, belonging to the sphere of artisanal work, and our case also proves that localised metalworking practices often depended on wide patterns of workforce migration. Contemporary writers on the metal trades, like Emanuel Swedenborg, were well aware of these preconditions for making quality products. They could observe and describe, but never reached a full understanding of the manipulation of matter.

Towards mid-century, this static system began to crumble, when hybrid people like Sven Rinman and Bengt Qvist, entered the world of production in a completely new way. Rinman was indeed a prolific writer on iron and steel, but also a man actively engaged in everyday work. This is clearly exemplified by his dealings in blister steel production, where he was involved in constructing new furnaces for the conversion of Swedish bar iron. The furnace test at Vissboda can be seen as the beginning of a process in which blister steel surpassed the production of crude steel, but it was also an early endeavour to scrutinise the relationship between nature and human work in a more systematic way. Not only did it affect ways to inspect the manipulation of natural resources, but it also pointed towards new ways of organising production. With Rinman's improved cementation technique, a new hierarchy was perceptible, one that was less dependent upon skilled craftsmen, and more suited to the Swedish *œconomia*. Qvist's engagements in the making of crucible steel demonstrate this development even further, with technical expertise in a more pronounced position within the Swedish iron and steel trade.

Rinman and Qvist belonged to what Tony Wrigley has labelled «the advanced organic economy», in which a static society was gradually eroded by changes in the spheres of production, commerce, science, and politics; they thought about concrete improvements, but could not foresee a period of prolonged progress. This was to change towards the end of the century, when yet another generation of travelling *savants*, like Eric Thomas Svedenstierna, saw the full effects of the «mineral-based energy economy» in British iron- and steelmaking. Experiencing how these changes left Swedish ironworks struggling «on the outer edge», Svedenstierna did not frame potential solutions in the language of cameralism, as his predecessors, but instead viewed the British development, with an industrial production based on technical advancement, as something to emulate: it was only to «tirelessly [follow] the direction of the age and hence the improvements arising». It was up to a «hybrid expert» of a later generation, Gustaf Ekman, to accomplish what Svedenstierna had envisioned. After several journeys to Britain, Ekman came to lead the quest for improvements at Swedish ironworks, with the «Lancashire method» combining transfers of British technology with a continuous reliance on charcoal. With the new technology implemented, ironmaking expanded, and the British market became once again the main recipient of Swedish bars. The relationship established a century before, between makers of high-quality Swedish iron and English steelmakers, was strengthened, as the new varieties supplied a rising, industrial, British steel production. With Svedenstierna and Ekman, the focus on ways of refining iron into steel and metal wares that dominated among eighteenth-century cameralists, was replaced by an emphasis on pig and bar iron making. Ekman's mission was not to develop the production of steel and metal wares, but instead to adapt Swedish ironmaking to a context of industrial progress.

Notwithstanding the developments from mid-eighteenth century, from Rinman's improved steel furnaces to the Lancashire-method, it was clear that the daily production still relied on working people and their manual dexterity. In 1831, when commenting on the challenges with the Lancashire forging, Ekman highlighted the artisans' «motions» and «training», thus reinstating the balance between «*episteme*, *praxis*, and *technē*» that was missing from Svedenstierna's analysis.

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Nicholas R. Amor

The origins of the putting-out or domestic system of industrial production in England[*]

The out-worker has long been seen as a key figure in the transition from feudalism to industrial capitalism. Operating from home, often using their own equipment, out-workers earned a piece-rate in return for their labour, but had no other stake in the financial success of the business. They stood half way between the artisans of the middle ages selling their products at the local market, and the waged proletariat of the industrial age toiling in dark satanic mills. Out-workers became well-established in woollen cloth production which was the most important industry in late-medieval and early-modern England and the first to develop a degree of specialization in the division of labour. They worked as carders and spinners who turned wool into yarn; weavers who interlaced yarn on a loom to produce cloth; fullers who washed the cloth to remove natural oils and give it a thick baize-like finish; dyers who added colour; and shearmen who gave it a smooth finish.[1] Clothiers brought each of them in turn the material on which they were to work and then took the product away to sell for profit. This was the essence of the putting-out or domestic system of production.

Ever since Marx wrote about domestic industry in *Capital*, historians have been fascinated by putting-out. In his influential volume, *Studies in the development of capitalism*, Dobb contended that capital began to penetrate production on a considerable scale, either in the form of a fairly matured relationship between capitalist and hired wage-earners or in the less developed form of the subordination of domestic handicraftsmen, working in their own homes, to a capitalist on the so-called «putting out system» (1946, 18).

His work triggered the famous academic debate that was published as *The transition from feudalism to capitalism*, and edited by Hilton who echoed Tawney (1938, 79-

* My thanks to Professor Mark Bailey, Dr John Lee and Professor Stephen Rigby for their comments on earlier drafts which have made this a much better paper; and to delegates at the 2022 Datini conference for their comments and questions. Needless to say, any remaining errors are entirely mine. Also, to The National Archives at Kew (TNA), Suffolk Archives (SA), and Professor Robert Palmer and his AALT team who made sources available to me.

[1] These workers are designated in various ways within this paper. When seeming to operate independently they are called «cloth-makers», and, when working for clothiers, as «out-workers». In other contexts they are called «cloth-makers» or «artisans».

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Referee List (DOI 10.36253/fup_referee_list)
FUP Best Practice in Scholarly Publishing (DOI 10.36253/fup_best_practice)

Nicholas R. Amor, *The origins of the putting-out or domestic system of industrial production in England*, © Author(s), CC BY 4.0, DOI 10.36253/979-12-215-0092-9.16, in Giampiero Nigro (edited by), *L'economia della conoscenza: innovazione, produttività e crescita economica nei secoli XIII-XVIII / The knowledge economy: innovation, productivity and economic growth,13th to 18th century*, pp. 263-285, 2023, published by Firenze University Press, ISBN 979-12-215-0092-9, DOI 10.36253/979-12-215-0092-9

80) and Power (1941, 4) in opining that «modern capitalism derived its initial impetus from the English textile industry» (1978, 156).

Britnell and Dyer both recognised the development of out-working in late medieval England, but downplayed its general significance. Britnell argued that the commercial institutions that underpinned capitalism emerged mainly between 1000 and 1300. He acknowledged that the organisation of industrial production of textiles through wage-dependent workers in the putting-out system was one facet of capitalism, but stressed «the restricted extent of the structural change within the woollen industry» and «the subsidiary importance of woollen cloth in the economy as a whole». In his view such industrial organisation was «unlikely to have affected more than a few thousand workers» (1999, 367-9). Dyer identified a class of workers who depend mainly on wages for their livelihood as a hallmark of capitalism, and argued that «a great extension in the dependency of workers came about with the development of the putting-out system». However, like Britnell, he concluded that «there was no wholesale increase in the wage-earning workforce» during the later middle ages (2005, 230; 232).

Lee contended that the putting-out system may have operated sporadically in parts of early-fourteenth-century England, but its use spread late in the century with the arrival of Flemish immigrants (2018, 18-21).[2] Their role in extending the system in England underlines its Continental origins. The great late-medieval wool textile industries of Flanders and Florence relied heavily on out-workers (Carus-Wilson 1987, 639-40. Munro 2003, 218-21). In Italy the merchant members of the *Arte della Lana* organized production of relatively cheap, coarse fabrics through variants of the putting-out system (Munro 2015, 113-4). Over a period of three years, Francesco di Marco Datini himself engaged no fewer than 1,000 out-workers, who in turn were involved in 6,088 distinct or partial operations, in making the cloth on which he built his fortune (Banaji 2020, 91). Nevertheless, the very fact that England became the first industrial nation gives particular importance to the study of the system there.

This paper is concerned with the nature and scale of the putting-out system in the English textile industry at the close of the middle ages, with particular reference to Suffolk, which was, by 1500, the nation's foremost woollen cloth producing county. It begins by explaining how the textile industry evolved in response to increased overseas demand for English cloth and in a way that enhanced the role of the clothier as the commercial link between artisans and merchants. The relationship between the clothier and out-workers is examined in the light of bequests in those wills of wealthy testators that were proven in the Prerogative Court of Canterbury (Prerogative Court of Canterbury). Finally, the scale of the industry and size of the workforce at the beginning of the sixteenth century are explored in detail. In this respect, the evidence of civil litigation within the Court of Common Pleas (Court of Common Pleas) is used to cast new light on these issues. Common Pleas was not the only forum for the resolution of textile disputes, although as a royal tribunal, with a nationwide jurisdiction and a minimum threshold of 40s for claims, it was well matched to the scale of the cloth industry and the long distance of the

[2] Kowaleski found evidence of putting-out in late fourteenth-century Exeter (1995, 150-52).

trade. We cannot assume that every plea by or against a clothier related to textiles, but there is no reason to suppose any variation over region or time in the proportion that did. The value of the litigation provides some indication, however imperfect, of the volume of trade and, in turn, of the scale of the industry.

1. Evolution of England's medieval woollen cloth industry

During the later middle ages woollen cloth overtook wool as England's major export. In the mid-fifteenth century such exports averaged about 40,000 broadcloths per annum. Within a hundred years they had risen to nearly 140,000 broadcloths.[3] In between time London's share of this trade grew from about 40 per cent to close to 90 per cent (Carus-Wilson, Coleman 1963, 96-98; 118-19. Barron 2000, 418. Quinton, Oldland 2011, 113). During the earlier period, cloth exports by the German merchants of the Hanseatic League from the headport of Ipswich (mainly from Colchester and Ipswich itself) had been substantial, outnumbering those from all other provincial ports combined (Lloyd 1991, 228-29), but after 1470 the Hanse more or less abandoned these East Anglian harbours. In consequence, the textile industries of Suffolk and Essex were increasingly targeted towards the London market and exports from there, rather than towards provincial sales (Amor 2016, 201-06). This migration of so much cloth export trade from East Anglia to London had major consequences.

As late as the 1460s cloth-making in Suffolk was relatively broad based. A few men turned out large numbers of cloths, but smaller scale producers, those manufacturing on average less than 33 broadcloths per annum, still dominated production (Amor 2004, 417). They accounted for nearly two-thirds of the cloth sealed and approved for sale by the alnager – without his seal it was unlawful to sell woollens whether intended for ultimate use in England or overseas.[4] Most such clothmakers probably had specialized skills in one or more stages of production, but they operated independently and contracted out those stages in which they were not proficient (Britnell 1999, 368). The fullers of Long Melford, a major textile manufacturing centre in south Suffolk, exemplify these small-scale producers. A rental of 1441/42 for the manor of Melford Hall names five fullers as tenants in Hall Street, which lay south of the Chad Brook from which they could source the plentiful supply of water so important to their trade.[5] Another six or seven fullers can be identified with reasonable confidence from the plea rolls of the Court of Common Pleas, making a total of at least eleven in just one street (Amor 2016, 163). The holdings of the Melford fullers were tiny, certainly not big enough to support subsistence agriculture, with only three extending to more than an acre and

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[3] The term «broadcloth» is used throughout this paper to mean whole cloths of assize or their equivalent in narrow cloths, commonly known as straits. One broadcloth roughly equated to four straits. For the purpose of their accounts, customs officials converted them all into cloths of assize (Quinton and Oldland 2011, 117).

[4] *Statutes of the Realm*, ii, 88. The alnager was a royal official or someone to whom the office was farmed out for a fixed payment.

[5] Suffolk Archives (SA) Bury St Edmunds, J/523.

none to more than two. However, one fuller had two shops on his land and another a small tenter-yard. These small-holdings can still be identified in a later estate map of 1613 and they help shape the frontage of Hall Street today.

These fullers had been drawn into textile manufacture for various reasons, but above all by a need for the income that could be generated from craft activity. The demographic collapse caused by the Black Death of 1348/49 and subsequent epidemics had profound economic and social consequences. On the one hand, labour scarcity ultimately pushed up the wages of peasants and artisans, raising their standard of living and increasing per-capita demand for better-quality, commercially produced cloth.[6] Nearly all this cloth was manufactured in England rather than, as had been the case earlier, being imported from the Low Countries. A combination of import controls on cloth and heavy export duties on raw wool helped transform the country into a net exporter of wool textiles. On the other hand, changes in the patterns of land ownership and land use – in particular engrossment of holdings, enclosure and a switch from arable to pastoral husbandry – resulted in «polarisation within village communities between larger landowners and smallholding craft workers and labourers» (Bailey 2021, 307). The move to pastoral husbandry reduced demand for agricultural labour and created a genuine concern about unemployment. As early as 1489 Parliament passed the Husbandry Act, lamenting the «leyeng to pasture londes whiche custumeably have ben used in tilthe, wherby ydilnes ground and begynnyng of all myschefes daily doo encreace».[7] The fullers' could not make a living from husbandry, but they could do so through their craft and by conducting relatively low value transactions with their immediate neighbours in Long Melford, or with residents of nearby towns such as Great Waldingfield, Kersey and Lavenham. Some of them, in turn, sold on to the Hanse.

From about 1470, control of Suffolk's textile industry became increasingly concentrated in the hands of clothiers. Their familiarity with London merchants and better access to city capital and credit gave them a competitive advantage over small-scale producers. The number of clothiers cited in the plea rolls of the Court of Common Pleas increased dramatically, while the number of other recorded cloth-makers showed a marked decline (Table 1). For several reasons the less enterprising of the cloth-makers became increasingly dependent upon out-work provided by the clothiers (Sutton 2010, 163). The exodus of the Hanse from the East Anglian ports broke any direct local route to export markets and the cash payments that the Germans had customarily made. Domestic demand remained slack during, and even after the prolonged mid-century depression. Until 1487 most London livery companies intermittently operated an anti-fair policy which prohibited members from travelling to the provinces to undertake business and expected provincials to

[6] The view that, after the Black Death, workers used their new-found economic muscle to push up real wages, has not gone unchallenged. In the immediate aftermath of the pandemic labour legislation may possibly have moderated wage increases. Munro argued that wages lagged behind price inflation until the 1370s (2003, 211-12); and Bailey opined that wage rates plateaued around 1400 (2021, 291).

[7] *Statutes of the Realm*, ii, 542.

come to them.[8] So, clothiers became essential linkmen between artisans and London merchants. By 1500 Suffolk's position as the leading cloth-making county had created an almost insatiable demand for wool, much of it brought in from other counties. Local woolmen had once supplied cloth-makers with wool, but their number was now in decline (Amor 2016, 109-10; 112-15).[9] Instead, clothiers bought the precious raw material direct from wool growers around the country and supplied it to out-workers themselves. Thus, the dependence of outworkers on clothiers was reinforced by their isolation from both customers and suppliers.

Tab. 1. **Number of different Suffolk clothiers, weavers, fullers and dyers engaged in Court of Common Pleas litigation at 5 yearly intervals during the two periods 1450-70 and 1490-1510**

	Hilary term 1450-70	Hilary term 1490-1510
Clothiers	29	115
Weavers, fullers and dyers	262	124

Notes: References to «clothier» include references to «clothmaker» and «clothman» which terms appear to have been synonymous and indeed interchangeable. Very few carders, spinsters or shearmen were cited in either period.

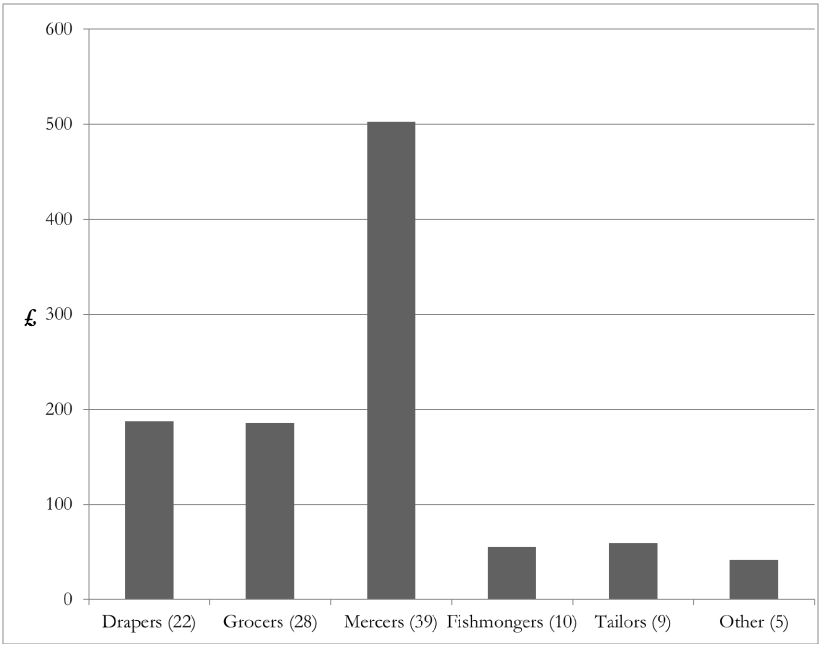
Sources: The National Archives (TNA) CP 40/756, 776, 796, 814, 834, 911, 931, 951, 971, 990.

Among London merchants it was the members of the mercers' company, many of whom traded as merchant adventurers with the Low Countries, who became the most important customers of Suffolk manufacturers. Owing to their dominant position in Antwerp, in the years either side of 1500 «their trade and wealth was reaching a zenith» and their share of denizen cloth exports through London was consistently in excess of 40 per cent (Sutton 2005, 318; 348. Quinton and Oldland 2011, 131). Sutton has explored the close links between London mercers and Suffolk, and the number of the county's more enterprising young men who went on to take apprenticeships and make their fortunes with that company. Among them were members of the Forthe family of Hadleigh and the Sturmyn family of Lavenham who numbered among the county's leading clothiers (2010, 165-66). In the second half of the fifteenth century the value of Suffolk clothiers' debt litigation with London mercers, as recorded in selected pleas of the Court of Common Pleas, was very nearly as much as with members of all the city's other livery companies combined (Graph 1).

[8] *Parliament Rolls of Medieval England*, vi, 402.

[9] This may be attributable to the legislation that was, from 1465, targeted against woolmen: *Statutes of the Realm*, ii, 410, 535-36.

Graph 1. **Value of Court of Common Pleas litigation between Suffolk clothiers and London merchants 1440-1500**



Notes: Each column records the value of litigation between Suffolk clothiers and members of that company and the number of disputes is stated at the bottom.

Source: TNA CP 40/716, 732, 736, 756, 758, 768, 788, 796, 807, 814, 826, 834, 837, 841, 853, 861, 871, 883, 885A, 887, 888, 889, 890, 891, 895, 907, 911, 919, 931, 943, 951.

The growth of the textile industry gave rise to a new status quo, with a hierarchy of merchants, clothiers and out-working artisans. The mercer and merchant adventurer Thomas Kitson made an enormous fortune before retiring to the comfort of his new home at Hengrave Hall outside Bury St Edmunds in Suffolk (Lee 2018, 88-91). Only a few clothiers, notably Thomas Spryng III of Lavenham, did as well as Kitson, but a significant number made more modest fortunes. Between 1450 and 1530 the wills of 79 wealthy Suffolk clothiers were proven in the Prerogative Court of Canterbury. The government's military survey of 1522 survives for the hundred of Babergh, the epicentre of the cloth industry in south Suffolk. It records 119 clothiers, of whom 82 (68.9 per cent) owned goods worth £20 or more. Only 5 out of 196 (2.6 per cent) artisans whose stated occupation identifies them as cloth-workers owned goods of £20 or more, but nearly half owned goods worth 40s or more (Pound 1986, 133). This latter group were essentially out-workers, and Cornwall has argued that their level of assessable wealth was sufficient to raise them above the poverty line. «They were not unaffected by the general prosperity of the district» and their relative affluence was indicative of «a wider, more varied range of jobs and responsibilities created by a more developed economy» (1988, 24-25). The flow of work was enough to keep them and their families busy.

The hierarchy was, however, a fragile one. When the textile boom came to an end hardship quickly followed. In the 1520s the industry was buffeted by a perfect storm. Warfare, poor harvests and famine in Continental Europe, as well as a trade embargo between England and the Low Countries, slashed overseas demand for cloth. As if that was not enough, Henry VIII made matters far worse by heavy and repeated demands for tax to finance his military ambitions in France. This culminated, in 1525, with the imposition of the Amicable Grant – an onerous levy on the goods of both laity and clergy. The consequences for Suffolk textiles were dire, since heavy taxation not only deprived both merchants and clothiers of the working capital necessary for the production and sale of cloth, but also sapped domestic demand for their fabrics. Clothiers were unable to provide regular work for out-workers, provoking civil unrest and generating a contemporary literature that provides important information about, and perhaps the first direct descriptions of, the putting-out system. A chronicler of the time, Edward Hall, recorded that the clothiers «called to them their spinners, carders, fullers, weavers and other artificers... and said, sirs we be not able to set you a work our goods be taken from us» (Lee 2018, 181). The duke of Norfolk reported to Cardinal Wolsey that a large and volatile crowd, numbering some 4,000 souls, many of them from the major textile centres of Lavenham and Brent Eleigh, had gathered two miles outside of Bury St Edmunds to protest the Amicable Grant, pleading that any offence they might commit was «only for lack of worke soo that they knewe not howe to gett theire lyvinge» (MacCulloch, Fletcher 2020, 143). Of the 528 indicted for involvement in this uprising, 188 (35.6 per cent) were cloth-workers and 415 (78.6 per cent) «must, by any standards, be regarded as desperately poor» (Pound 1999, 320; 323). The economy of south Suffolk in 1525 was far less buoyant than it had been just three years before.

In the next section, we will look at the bequests made by clothiers throughout England to their out-workers and ask what they tell us about the nature of their relationship with that workforce.

2. The relationship between clothiers and out workers

At least sixteen clothier testators, out of a total of 179 between 1450 and 1530, remembered out-workers in Prerogative Court of Canterbury wills, all but one of whom came from one or other of five counties and most of whom came from smaller settlements rather than large towns (Table 2 and Figure 1). In the few cases when one can look behind wills to probate documents one finds more such bequests, such as that of Stephen Draner of Cranbrook in Kent.[10] We can be confident that many other clothiers relied on out-workers, but did not reward their efforts in the same way. Some bequests were generous, but most were only of a few pence and generally less than bequests made to household servants. Christopher

[10] TNA PCC, Prob 2/525.

Pyarde of Trowbridge in Wiltshire did no more than forgive the debts of his spinners and weavers in full up to the first 12d and half of any excess which, at least, indicates that he paid them in advance in cash, rather than in arrears and in kind as was so often the case (Amor 2016, 125). The general parsimony suggests that personal relationships between clothiers and out-workers were rarely particularly close which might, in turn, explain why there were so few such bequests.

Spinsters and weavers were each remembered in nine of those wills, fullers in seven, shearmen in two, and carders, combers and dyers each in just one. Although this database is very small, it supports some tentative conclusions. Combers, who helped prepare the yarn for worsteds, were only mentioned once, reinforcing the view that the putting-out system was largely confined to the manufacture of woollens rather than worsteds. Worsted production remained embedded in the master craftsman's workshop.[11] Out-workers were more often engaged in cloth production, than cloth finishing. Spinning, weaving and fulling were, relative to finishing, unskilled tasks that could be trusted to artisans with only limited training and supervision since England's textile industry was orientated towards standard rather than top quality fabrics. Clothiers looked well beyond their own towns for labour. Thomas Sturmyn of Lavenham bequeathed 2d to each spinner in Glemsford and Stoke-by-Clare, the latter village being more than 14 miles by road from his home. Only 13 clothiers mentioned looms in their wills, none at all mentioned spinning wheels. Some clothiers' probate inventories included references to looms, such as that of Robert Rychardes of Dursley in Gloucestershire who did own broadlooms, but with a total value of only 40s.[12] We can surmise that most out-workers used their own equipment which could be acquired at modest expense (Amor 2016, 144-5). Dyeing and shearing required higher levels of skill and training. A working knowledge of organic chemistry was necessary to dye cloth the right colour. A good eye and a steady hand were essential for shearing which was generally the final stage in textile production – one slip of the shears could damage or even destroy a broadcloth that had been weeks in the making. Many clothiers may have been reluctant to farm out this finishing work and preferred to keep it in-house. At least 14 owned tenter-yards, in which to dry, stretch and nap their cloth once fulled; at least 26 owned stocks of dye; and a similar number owned dyehouses or dye vats. Of the dyes, woad, which turned cloth blue, was the most frequently mentioned, although three Suffolk clothiers also owned stocks of madder which turned cloth red or orange. The two dyes could be mixed to produce other colours. Even when the finishing stages in textile production were not brought in-house, they were often carried out in London or even in Antwerp rather than locally, which may help to explain the rarity of bequests to dyers and shearmen.

In the next section we estimate the scale of the industry and the size of the workforce at the close of the middle ages with a view to assessing the importance of out-working within the national economy.

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[11] Woollens were manufactured using short-staple wool as distinct from worsteds which used long-staple wool. The production methods were also different (Amor 2016, 18).

[12] TNA PCC, Prob 2/57 (source courtesy of John Lee).

Tab. 2. **Clothiers' bequests to outworkers 1450-1530**

Reference PROB 11	Date	Testator	Of	Bequest
12/298	1500	William Barley	Potterne, Wilts	To each towker 3s 4d
10/299	1494	Richard Bedford	Newbury, Berks	To 30 weavers 20 yards of canvas divided among them as executors shall determine
09/27	1491	John Brigge	Salisbury, Wilts	To Robert Rumsey weaver 10 marks both for his own use and towards an exhibition for Robert's son William to attend as a minor scholar the new college of Winchester [at Oxford] in equal shares
19/386	1519	Thomas Crystmas	Colchester, Essex	To each retainer who be fullers, weavers and shearmen whose names be comprised in a schedule annexed to will 6s 8d. To each spinner that of old long time have continued with me an ell of linen cloth price 6d. Schedule names John Raynolde weaver, Robert Willoughbye weaver, John Orell weaver, [no forename] Pollesfelde weaver, Robert Parker weaver, John Wodman shearman, Richard Clerke shearman.
11/213	1495	John Golding	Glemsford, Suffolk	To each spinner 'out of town as in the town' 12d
10/401	1495	Thomas Mayhoo	Chewe, Somerset	To John Johns toker 6s 8d
6/171	1473	John Motte	Bildeston, Suffolk	To each person who has worked for me in spinning, fulling and weaving in the shire of Suffolk 6s 8d
19/207	1518	Thomas Paycocke	Coggeshall, Essex	To Thomas Gooday shearman 20s and each of his children 3s 4d. To Edward Gooday shearman 16s 8d and his child 3s 4d. To John Beycham weaver £5. To Robert Taylor fuller release of any debt plus 3s 4d. To other weavers, fullers and shearmen 12d and 'they that have wrought me very much work' 3s 4d. To combers, carders and spinners total of £4.
20/214	1521	Christopher Pyard	Trowbridge, Wilts	To those spinners and weavers who owe less than 12d release of entire debt and to those who owe more release of 12d plus half the excess
11/743	1514	Stephen Raynham	Nayland, Suffolk	To each 'weaver that hath wrought with me and now doth' 20d. and each spinner 8d
7/352	1486	Thomas Spring II	Lavenham, Suffolk	To spinners, fullers and weavers 100 marks
16/289	1510	William Spryng	Long Melford, Suffolk	To each poor spinner 4d
22/368	1527	Richard Stubbington	Farnham, Surrey	To each shearman and dyer within the town of Farnham who serves me and has served me one year 4d each to pray for my soul
10/42	1493	Thomas Sturmyn	Lavenham, Suffolk	To each spinner in Glemsford and Stoke-by-Clare 2d
17/385	1512	John Tyler	Wells, Somerset	To each weaver and touker 4d
15/94	1505	Thomas Webbe	Dedham, Essex	To each spinner an «Aporn» cloth price 4d

Notes: The terms «toker», «touker» and «towker» all mean fuller.

Sources: TNA PROB 11.

3. Number of cloths and cloth-workers

Both Britnell and Dyer downplayed the importance of the putting-out system based on their low estimates of the number of people engaged as out-workers in the textile industry. This, in turn, assumes that the scale of the nation's woollen cloth industry at the close of the middle ages was limited – an assumption worth revisiting, although the sources do not permit any definitive conclusion. Various historians have tried to estimate the scale of the medieval industry and the size of the workforce (Table 3).

Tab. 3. **Historians' estimates of national production of broadcloths (or equivalent) per annum for domestic use and export and size of workforce**

As at year(s)	Historian	Total production	Workforce
1391-95	Oldland	159,525	X
1394-98	Gray	49,308	X
1394-98	Postan	49,308	15,000
1394-98	Carus-Wilson	X	17,000-20,000 (export trade only)
1441-45	Oldland	196,456	X
Late 1460s/early 1470s	Heaton	39,345	X
1491-95	Oldland	209,792	X
1500	Dyer	200,000 to 240,000	20,000 to 24,000 weavers
1541-45	Oldland	308,056	264,137
1540-47	Bowden	187,125 (inc worsted)	X
1590	Muldrew	35,450,538 lbs ≈ 299,602 broadcloths	225,083 spinners

Notes: Unless otherwise stated, these figures exclude worsted. In the 1390s exports averaged just under 40,000 broadcloths per annum (Quinton and Oldland, 2011, 112). X means no estimate.

3.1 Previous estimates of total production

In pioneering work in the early 1920s both Heaton and Gray separately analysed alnage accounts which record woollens, but not worsteds, approved for sale. Gray concluded that, by the mid-1390s, annual production had reached marginally under 50,000 broadcloths (1924, 34). According to Postan, thereafter the fortunes of the industry were mixed until the late 1460s or 1470s when «the late fourteenth century levels of production were decisively overtaken and the industry resumed its uninterrupted progress» (1950, 232). Heaton diligently collected alnage accounts from as many counties as he could find for the late 1460s and early 1470s, when the generation-long economic depression was drawing to a close (1920, 85). On the basis of these accounts he calculated that England's total output was just short of

40,000 broadcloths (Table 4).[13] The alnage accounts have long been a controversial source, Carus-Wilson being very critical of them (1967, 291). Since the farming out could be subject to intermittent competitive tender the farmer might well understate the number of sealed cloths.[14] Heaton's estimates are set out in Table 4, but must be treated with extra caution because he only used one set of accounts for each county. Using other sources relating to the English wool trade, Bowden contended that, during the period 1540-7, when annual exports averaged 124,750 cloths, half that number (62,375) was supplied to the domestic market (1962, 37).

Tab. 4. **Heaton's figures for county cloth production as recorded in alnage accounts**

County	Number of broadcloths	% of total
Berkshire	1,293.5	3.3
Devon	1,036.5	2.6
Essex	2,627.5	6.7
Gloucestershire (inc Bristol)	4,874.5	12.4
Hampshire	1,450.5	3.7
Kent	1,027	2.6
Somerset	4,981.5	12.7
Suffolk	5,188	13.2
Wilts	4,310	11.0
Yorkshire	4,972	12.6
Other counties	7,584	19.3
Total	39,345	

More recently, historians have suggested that «the domestic cloth market was far greater» than this earlier generation thought (Oldland 2016, 233). On the assumption that «in 1500 a million-and-a-quarter adults were buying annually an average of 3 yards of cloth each», Dyer speculated that domestic demand might have been as high as 160,000 broadcloths per annum.[15] By that time exports had risen to over 80,000 broadcloths per annum, so total national output could not have been less than 200,000 and might have approached 240,000 (2005, 149-50). Using a similar split between domestic and export demand, Oldland contended that, in the second half of the fifteenth century, domestic consumption rose from 140,000 to 150,000, and total production to over 200,000 broadcloths, and that by the early 1540s production had reached 308,000 broadcloths per annum. He regarded these as conservative estimates (2014, 29; 39. 2016, 235).

[13] By way of comparison, in 1432-3 the revenue raised 'from the farms of subsidies and alnage' was £720 10s 1d, which equates to alnage and subsidy on 38,427 broadcloths: *Parliament Rolls of Medieval England,* iv, 433.

[14] *Calendar of Fine Rolls 1445-52*, 6. [COMPLETE REFERENCE?]

[15] Broadberry et al reckoned that, in 1300, domestic woollen cloth consumption amounted to 1.18 square yard per person per annum which equates to 0.67 yard of broadcloth, a broadcloth being 1.75 yard wide (2011, 10). Although standards of living undoubtedly rose after the Black Death, it seems unlikely that both Broadberry's and Dyer's estimates are correct.

Oldland's work drew on that of Muldrew who estimated that, in 1590, total output of woollens was 35,450,538 lbs (2012, 518), equivalent, according to Oldland, to 299,602 broadcloths (2014, 39). However, Muldrew candidly admitted that his calculation was «a complex and necessarily speculative process», based on the famous *Scheme* of Gregory King who noted that, in 1688, 2 to 3 yards of cloth were purchased per person per annum. That followed «the great reclothing of rural England» during the Restoration Period when «there is much evidence of a surge in cloth production» (Muldrew 2012, 500; 511; 514-5). Furthermore, between 1590 and 1688, the textile industry had been transformed so that, by the later date, nearly half of the aggregate weight of cloth was devoted to the lighter and cheaper fabrics of the new draperies (Muldrew 2012, 518). King's *Scheme* is, therefore, not a very reliable basis on which to calculate cloth production in 1590, let alone 1500.

Hence estimates of the scale of the textile industry vary markedly. The most pessimistic calculations indicate that total production for both domestic sale and export peaked shortly before 1400 at about 50,000 broadcloths per annum, and only began to rise again 70 years later. The most optimistic suggest a first post-Black Death peak in the early 1390s at about 155,000 broadcloths, rising to over 196,000 broadcloths by the early 1440s, and finally reaching a zenith a century later at about 308,000 broadcloths. The variances here carry important implications for our assessment of the extent of out-work in England at the end of the middle ages.

3.2 Previous estimates of total workforce

Postan contended that, in the mid-1390s, the production of 50,000 broadcloths would have required the equivalent of 15,000 full time workers. Carus-Wilson preferred a higher figure to take account of the labour intensity of carding and spinning, reckoning that between 17,000 and 20,000 full-timers would have been needed to make the 40,000 odd broadcloths that were exported each year (1967, 261n). More recently, historians have used various other methodologies to estimate workforce size. Both Britnell (1997, 234) and Dyer (2005, 149) suggested that each weaver could produce ten broadcloths per annum. Using Flemish evidence of productivity, Oldland reckoned that, by the early 1540s, 264,137 cloth-workers were engaged in textile manufacture – as many as 15-16 per cent of the adult workforce (2016, 235-6). Muldrew calculated that, in 1590, 225,083 spinners were at work in England (2012, 518). If so, the putting-out system was already established on a massive scale in England.

3.3 Revised estimates

In view of these conflicting opinions as to the scale of the industry and the size of the workforce, let us now make revised estimates using four sources, namely alnage accounts, plea rolls of the Court of Common Pleas, wills enrolled in the Prerogative Court of Canterbury and enrolled customs accounts.

If Heaton's alnage figures (Table 4) are compared with the evidence of the plea rolls of the Court of Common Pleas (Table 5), a subtly different picture emerges of the relevant importance of each county's output in the closing years of the fifteenth century and the opening years of the sixteenth. The Court of Common Pleas evidence indicates that the output of each of Essex and particularly Kent was comparable to that of each West Country county which would suggest that their alnage account figures are too low. Although the value of each county's Court of Common Pleas clothier litigation varied from year to year, there is no pattern in the figures to suggest that, in the 1470s, the Essex and Kent textile industries were still relatively under-developed. Thus we have strong grounds for arguing that Heaton's 40,000 broadcloths are an under estimate. Arriving at a more accurate estimate is no easy task, but if the output of each of Essex and Kent was similar to each of the West Country counties, then that adds about 5,000 broadcloths to the total. Allowing for omission, evasion, and under-counting, between 5,000 and 15,000 additional cloths might be trawled from across England. An uplift of Heaton's total by between 25 and 50 per cent would not be unreasonable. Even so, it is difficult to conceive that the ultimate total would have been in excess of 60,000 and, as Postan contended, was probably at a similar level to output in the late 1390s.

Tab. 5. **Court of Common Pleas clothier debt litigation 1475 to 1510**

County	No. of clothiers	No. of debt pleas	Total value of litigation (£)	% of total value
Berkshire	40	52	808	4.9
Essex	96	155	1,822	11.0
Gloucestershire (inc Bristol)	84	125	1,879	11.3
Kent	147	249	2,332	14.1
Somerset	124	168	2,213	13.4
Suffolk	277	478	4,470	27.0
Wilts	66	71	1,225	7.4
Other counties	147	172	1,826	11.0
Total	981	1470	16,575	

Notes: When enrolling a plea, as required by the Statute of Additions 1413 the residence and occupation of the defendant had to be stated, but not those of the claimant. So, most of this data is drawn from the defendant side. Nevertheless, analysis of the data is like-for-like. Per-capita use of the court by the populations of each county was broadly similar (Stevens 2012, 232-4). In each of the seven principal clothier counties the ratio of clothiers to other cloth-makers, cited in the plea rolls, was again broadly similar (Amor 2016, 222-39).

Sources: TNA CP 40/853, 861, 871, 883, 885A, 888, 891, 895, 907, 911, 919, 931, 943, 951, 959, 971, 983, 990.

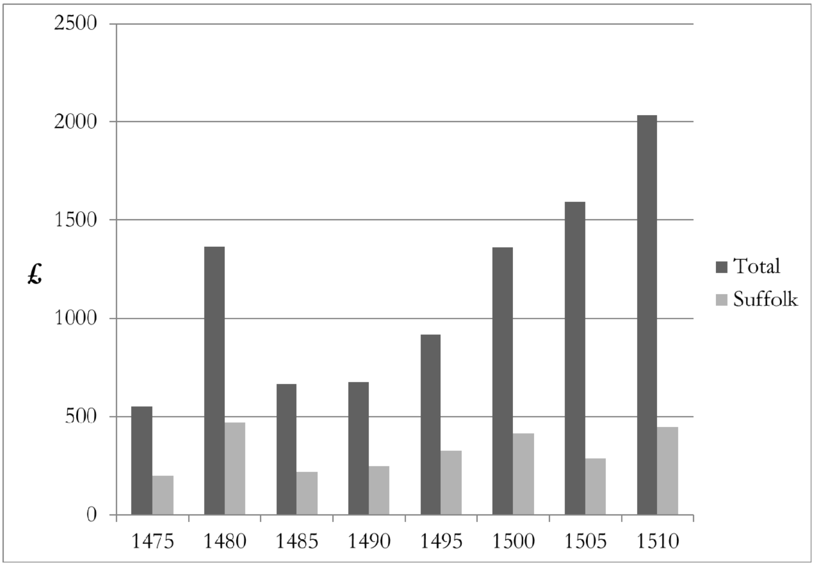
This Court of Common Pleas evidence, and in particular the value of the debt litigation, can also be used to ascertain the trajectory of the industry in the 35 years after 1475 and estimate the scale of the industry at the end of that period (Graph 2). The starting date of this analysis is 1475 by when the clothier had become a well established figure in the textile industry – certainly in Berkshire, Essex, Kent, Gloucestershire (including Bristol), Somerset, Suffolk and Wiltshire which we shall call the principal clothier counties (Figure 1). The end date of 1510 gives a lengthy period of thirty-five years during which England enjoyed «two sharp bursts» of export growth (Britnell 1997, 228) and price inflation was close to zero. It predates the sharp rise in inflation during the early years of Henry VIII which would distort later data.

Fig. 1. **The principal clothier counties**

Format: David Addy.

The plea rolls show that, between 1475 and 1510, the total value of clothier litigation in each of the quinquennial Hilary terms studied rose from £552 to £2035, an increase of 369 per cent. Growth was steady across the period, with the exception of the mid to late 1480s when the industry, trade and the operation of Common Pleas were probably all disrupted by the dynastic struggles that culminated in the defeat of Richard III by Henry VII at the battle of Bosworth Field, and also by a trade embargo with Burgundy.

Graph 2. **Value of Court of Common Pleas clothier debt pleas 1475 to 1510**



Notes: Generally, the business of the court was in decline during the course of the fifteenth century, although the rate of decline slowed in the second half of the century (Stevens 2012, 228).

Sources: TNA CP 40/853, 871, 891, 911, 931, 951, 971, 990.

An even clearer indication of the real scale of growth in the textile industry over this period is provided by adding to the value of clothier debt litigation that of other cloth-makers, particularly master weavers, fullers, dyers and shearmen. By 1510 clothiers had largely displaced other cloth-makers in the plea rolls in the principal clothier counties, and accounted for 85 per cent of the value of textile litigation. What had happened to the former cloth-makers who had disappeared from the court? A number had re-designated themselves as clothiers, some through highly successful careers. Many cloth-makers were, however, downwardly mobile, displaced by the operations of clothiers and now tied as out-workers to their more enterprising colleagues, competing alongside the ranks of semi-skilled peasants seeking to augment their incomes through some textile piecework. In other cloth-producing counties, notably Norfolk and Yorkshire, in 1510 the proportion of cloth-makers remained higher, suggesting that clothiers were less prominent there and the semi-independent producer lasted longer. The rise of the clothier and the outwork system was mainly a feature of the most intensive, commercial, and export-focused areas.

The addition of the value of other cloth-maker litigation points to a much more modest increase in production between 1475 and 1510 (Table 6). Over that period, across the country as a whole aggregate growth in the value of Court of Common Pleas debt litigation was 58 per cent; in the principal clothier counties 70 per cent, or just over 1.5 per cent annualized; and in other counties just 45 per cent, or just over 1 per cent annualized. If the data reflects a true increase in output, then by the standards of the pre-modern textile industry, these rates are still impressive (Broadberry, Campbell, Klein 2015, 148). The data also suggests that output in the clothier counties, where the putting-out system was in use, increased more than elsewhere.

Tab. 6. **Value of Court of Common Pleas debt pleas 1475 and 1510**

Litigation	**1475 (£)**	**1510 (£)**	**% increase**
All counties – clothier	552	2035	369
All counties – clothier and other cloth-maker	2374	3752	58
Principal clothier counties – clothier and other cloth-maker	1228	2089	70
Other counties – clothier and other cloth-maker	1147	1663	45

Sources: TNA CP 40/853, 990.

If we multiply the total output figure calculated from Heaton's earlier alnage accounts as adjusted (max. 60,000 broadcloths) by the increase in the value of the textile litigation (58 per cent) then, for the opening years of the sixteenth century, we might arrive at national production as high as 100,000 broadcloths per annum.

Tab. 7. **Wills proven in the Prerogative Court of Canterbury 1450-1530**

County	**Clothier wills**	**Other cloth-maker wills**	**Bequests to out-workers**
Berkshire	10	3	1
Essex	15	2	3
Gloucestershire (inc Bristol)	8	5	0
Kent	10	0	0
Somerset	18	3	2
Suffolk	79	3	6
Wiltshire	25	1	3
Others	14	67	1
Total	179	84	16

Notes: Wills were generally proven in the Prerogative Court of Canterbury if the testator (a) lived in the south of England and (b) owned possessions in more than one diocese or (c) owned possessions with a value in excess of £5 (£10 in London): <https://www.nationalarchives.gov.uk/help-with-your-research/research-guides/wills-or-administrations-before-1858/> (2023-01-31)

Source: TNA PROB 11

The evidence of the wills complements that of the plea rolls (Table 7). Nearly all clothier testators came from the small towns and villages of the principal clothier counties. In each of these seven counties a significant number had been sufficiently successful and accumulated enough wealth to prove their wills in the Prerogative Court of Canterbury. Such men relied on teams of out-workers, a fortunate few of whom were, as considered above, remembered with bequests in the wills. Far fewer other cloth-makers achieved such success and nearly half of those who did so worked in London's cloth-finishing industries.

Although enrolled export figures are well documented, they are not without their limitations. Oldland contended that in the fifteenth century they under estimate, by about 5 per cent, the volume of cloth leaving the country. Cheap narrow cloths were not subject to the cloth custom, while others that were charged were often longer than the standard cloth and became heavier over time (2014, 43). Worsted exports were counted separately. No doubt some cloth was smuggled out, but probably not much (Carus-Wilson, Coleman 1963, 21-23; 199-200). The export numbers are generally regarded as reliable. In the late 1390s they were similar to those in the late 1460s/early 1470s, at just under 40,000 broadcloths per annum, and during both periods were about 80 per cent of alnage figures as adjusted. By the opening decade of the sixteenth century exports had doubled to about 80,000 broadcloths per annum (Quinton and Oldland 2011, 112-3) which, again, was about 80 per cent of our estimate of national output given above. This suggests that the bulk of commercially produced and sealed cloth was sold abroad, rather than to the domestic market. The consistency of the ratio seems more than a coincidence. Furthermore, the annualized growth rate of cloth exports between the late 1460s and the late 1520s was 1.65 per cent, very similar to the growth rate of the value of Court of Common Pleas debt litigation in the clothier counties analysed above (Britnell 1997, 228).

Turning to the size of the national workforce, the Suffolk alnage accounts for the years 1465/66 to 1468/69 provide a good starting point.[16] Prepared by the Crown servant William Whelpdale whom Britnell considered «an experienced and trusted receiver of royal revenues», they were «if not a perfect mirror of reality […] at least the fruit of an attempt to make them so» (1986, 187-8). As such they provide a rare insight into the real world of medieval cloth-making. These accounts reveal that 577 Suffolk cloth-makers presented Whelpdale with just over 5,000 broadcloths a year for approval (Amor 2004, 417). In order to estimate the size of the county's total textile workforce, some further methodological steps are needed. The largest producer was John Stanesby of Bildeston who presented 2,400 narrow cloths in 1467/68, for which he would have needed the help of about 30 weavers and 28 fullers, as well as carders and spinsters to whom we refer below (Amor 2016, 200, based on formulae of Munro 2003, 196-7; 220). If any of his cloth was finished locally then he would also have called on the expertise of dyers and shearmen, some of whom numbered among the 577.[17] A small elite that included Stanesby and another 22 clothiers were responsible for nearly 40 per cent of total output and would all have needed similar help. Over the four years, 303 of the 577 cloth-makers each manufactured on their own behalf less than 16 broadcloths in

[16] TNA E 101/342/25, 101/343/2, 4, 5.

[17] Such as Robert Cake of Stowmarket: TNA CP 40/796, m. 62v.

total, so probably spent much of their time working for this elite. Almost certainly, other weavers and fullers helped out but manufactured nothing for themselves and so remain invisible. If we add the invisibles, as well as apprentices and journeymen from the towns, it would not be unreasonable to round 577 up to say 800. [18] Most carding and spinning was undertaken by women and this work accounted for about two thirds of the hours required to produce cloth (Tawney and Powell 1924, 216-7). A hundred years earlier the fragmentary poll tax returns of 1381 for Suffolk are replete with names of spinsters in nearly every recorded village (Fenwick 2001, 505-36). It is evident from those wills in which looms were bequeathed to widows that some of these women were also competent weavers.[19] Only 15 of the 577 named cloth-makers were female, so the vast majority of those carders, spinsters and weavers are also invisible. Adding them to the equation could boost numbers from 800 to as high as 2,500 cloth-workers, or one for every two broadcloths – a ratio similar to that of Carus-Wilson's mentioned above. In estimating the size of the workforce in later years, some allowance should perhaps be made for productivity gains arising from greater use of spinning wheels and fulling mills, but this must be set off against the additional man-hours necessary to manufacture cloth that became increasingly heavy from the mid-fifteenth century.

So, our revised estimates suggest that, in 1510, the combined national output for both domestic and overseas markets was about 100,000 broadcloths and the workforce about 50,000. The four sources confirm and support each other. Like Bowden, one can conceive that domestic demand might have been half that of the export market and find another 20,000 broadcloths to make up the difference. This, however, would still be well below the figures proposed by Dyer and Oldland. Why should that be? Several explanations present themselves. Perhaps most domestic demand was met by black market cloth that escaped the alnager's attention, or by homespun which was not his concern, or by secondhand cloth that had already received his approval.

By its very nature the black market is difficult to measure. Bridbury certainly thought it substantial, because alnage

> was an excise, and excise is notoriously a tax which is very much easier to evade than a duty which is imposed where trade must concentrate […] evasion was always easier in the countryside than in towns (1982, 52).

The alnage was, however, a very light tax, probably less than 1 per cent of value, so there was little incentive to evade it and run the risk of forfeiting the cloth. Customs officials are likely to have spotted unsealed cloth so most of it must have been sold in the domestic market. If in the early 1500s, in addition to exports of 80,000 broadcloths, domestic demand was 160,000 broadcloths then an implausibly

[18] For apprentices and journeymen see the 1477 ordinances of the Bury St Edmunds weavers: SA Bury St Edmunds, B9/1/2. Only nine clothiers remembered apprentices in the 179 PCC wills.

[19] In 1495 Bennet Wareyn of Bury St Edmunds bequeathed a loom to each of his sons, but reserved for his widow the right to continue using them as long as she «wull use wevyng»: SA Bury St Edmunds, 34 Pye.

high proportion of those would have been unsealed. Assuming our growth estimates are correct, Heaton's alnage figures would have to be uplifted not by 25 to 50 per cent, but by closer to 300 per cent. In Suffolk William Whelpdale might have approved 5,000 broadcloths, but he would have overlooked 15,000, making a total of 20,000 and requiring a workforce of say 10,000. It seems inherently unlikely that such a diligent Crown servant could have been so misled. Furthermore, by the early-sixteenth century the county's output would have risen to 34,000 broadcloths and its workforce to an improbable 17,000 – nearly a third of the adult population (Cornwall 1970, 38).[20]

As for homespun cloth, Oldland himself downplayed its importance after the Black Death (2014, 41). The secondhand market may have been more important than Dyer thought when he described it as one reminder «of pockets of continued urban poverty» (1989, 207). Medieval clothes were made to last. They were stolen from more affluent households and were frequently passed down from one generation to the next as prized bequests. A thriving market for the sale of repaired and secondhand clothes operated in London and elsewhere.[21] In the Suffolk town of Newmarket *le Shraggeryrowe* was a trading row dedicated to the sale of old clothes (Sear, Sneath 2020, 105). According to Staples, fripperers «were not simply dealers in rags or cast-off clothing [...] the sale of secondhand clothing encompassed individuals of varying economic status, some who were quite wealthy» (2010, 171).

A final possible explanation for the discrepancy in the figures turns on the use for clothing of other fabrics not included in the official figures. The expansion of luxury double worsted production in Norwich contributed hugely to the economic success of that city. The rural cloth-makers of north-east Norfolk manufactured a much lighter and cheaper worsted that would have found a ready market among less affluent consumers. Certainly, worsted was available for purchase from drapers in Bury St Edmunds.[22] In Hilary term 1510 the weavers of Norfolk accounted for nearly a third of the value of their craft's nationwide Court of Common Pleas debt litigation. Linen was another material that was used for items such as shirts and smocks and imported in ever increasing volumes. Fur and silk were worn by a wealthy elite.

Whatever the explanation, the discrepancy remains hard to resolve. Is it possible that Dyer and Oldland have over estimated the size of the domestic market for cloth? There was no reason for domestic demand to have grown significantly in the closing years of the middle ages. Indeed, by reference to the total number of sheep and the wool yield from each animal, Broadberry et al contended that the textile sector contracted in the second half of the fifteenth century. If they are correct, then, since overseas sales undoubtedly increased over that period, the domestic

[20] In 1522, 15.9 per cent of those counted in the Babergh military survey were engaged in textiles (Pound 1986, 133). Keibeck estimated that, in 1601, 12.6 per cent of Suffolk's male labour force was engaged in textiles, rising to 16.3 per cent by the end of the seventeenth century, before trailing off thereafter (2016, 646).

[21] https://blog.history.ac.uk/2021/02/recycling-and-upcycling-waste-in-the-late-medieval-urban-economy/ (courtesy John Lee) (2023-01-31)

[22] TNA CP 40/951, m. 392v.

market would have shrunk significantly (2015, 109; 112; 138; 146-7).[23] Any increase in the country's population was modest. Cornwall postulated a rise between 1430 and 1522-5 from 2.1 million to 2.3 million (1970, 44), figures broadly accepted by Broadberry et al (2015, 20-2). However, Smith has identified a mortality cycle «after 1450 when both the levels of life expectation worsened among adults alongside a growing instability in the death rate in that age group» (2012, 82). Without doubt, any demographic recovery was insipid and only began to accelerate from the second quarter of the sixteenth century. As for the country's overall economic performance, Britnell dismissed any idea of a high rate of growth between 1470 and 1529, identifying «only patchy and localized development» and also «considerable slack in home demand» for woollen cloth (1997, 241).

Notwithstanding the reservations of Broadberry et al, the output of woollen cloth did almost certainly grow between 1475 and 1510, from perhaps 60,000 to as many as 100,000 or even 120,000 broadcloths per annum, providing work for as many as 60,000 cloth-workers, but not to the extent envisaged by the higher estimates of the scale of production and the size of workforce.

Conclusion

During the late middle ages the out-worker emerged as a key figure in the wool textile industry of southern and eastern England. From about 1470 the concentration of overseas trade through the port of London prompted the rise, largely in rural locations, of the clothier and the decline of the independent cloth-maker. Some clothiers built substantial businesses by networking with London merchants and engaging out-workers to help meet demand by performing more laborious and lower skilled tasks in their own homes. This created a hierarchy of merchant, clothier and artisan which worked well while export demand remained buoyant. However, changes in the patterns of land ownership and land use after the Black Death had caused greater polarization in village society and denied many out-workers a livelihood from husbandry. So when, in the 1520s, a combination of events undermined the industry and caused unemployment there followed mass poverty and civil unrest among the lower orders. Many of them had no other means of livelihood to fall back on.

Between 1475 and 1510 the textile industry and cloth exports were two rays of light against a drab backdrop of insipid demographic and economic growth. Nevertheless, domestic demand remained weak and at least two in every three commercially manufactured cloths were sold overseas. To judge by Court of Common Pleas debt litigation, the industry expanded at an average rate of between 1 and 1.5 per cent per annum, and was strongest in the seven counties where the clothier had become the dominant figure and putting-out the main means of production. Total output and the number of cloth-workers were not as high as some historians have postulated and involved only a relatively small fraction of the total population, so the putting-out system did not make late-medieval England a capitalist nation. Nev-

[23] To the contrary, Oldland argues that sheep numbers rose dramatically from 1450 to the mid-sixteenth century, and that wool yields were higher than some have suggested (2014, 25; 42).

ertheless, it transformed cloth-making in some regions, so must be regarded as a major step-forward in the organization of the industry, and one that enabled the country to meet escalating overseas demand and move further down the road towards capitalism.

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Joran Proot

The economic revolution in book design that went unnoticed: changing paper thickness in folios, quartos and octavos. The case of the Southern Netherlands, 1473-c. 1550

1. Radical changes in book production

The introduction in the West by Joannes Gutenberg (c. 1400? †1468; Bechtel 1992, 16) of printing with moveable type prompted a radical change in the production, distribution, and consumption of printed objects, not least of books. Once the "black art" had been made perfect and had been ran in, one press could print one sheet on both sides (inner and outer forme) in one colour (black) per day on extensive printruns. Gutenberg's 42-line Bible was probably printed on a run of about 158 to 180 copies (White 2017). In general, scholars maintain the number 500 for a typical fifteenth-century printrun (Schweitzer-Martin 2022, 152). As far as this is documented, printruns in the Southern Netherlands in the fifteenth century ranged between 100 and 300 copies (Adam 2018, I, 110-111). In the sixteenth century printruns increased to 1,250 copies and more (Imhof 2014, I, LXXXII). It goes without saying that those production times are incomparable with those of manuscripts. By way of example, one could cite one of the copies of the *Elsässissche Legenda aurea*, a large folio written in cursive script (which was probably not as slow as the most formal scripts), kept in the Bibliothek des Priesterseminars, Rottenburg (Cod. 11).[1] The production of the second part only of this extensive text took seven months, from Advent 1463 until 24 July 1464, which comes down to four pages in three days (Williams-Krapp 2019, 65). In that time, a press would produce four times as many pages (12 pages in folio, or three printing sheets recto and verso). Moreover, this would not result in a single copy, but in several hundreds of them – a multiplication in speed by a factor 1,000 and over.

Gutenberg tried to keep the tools and techniques he had developed secret for his competitors, hoping to capitalize on his investments first, and to reimburse his backers. After a court case, Gutenbergs fincancial backer and business partner Johann Fust started his own printing shop (Füssel 2019, 43), and the «art of writing artificially» started to spread, first in Mainz, then in the wider region, subsequently travelling to some 300 different cities and towns all over Europe (Sordet 2021, 199). By the end of the fifteenth century several hundreds of printing shops had

[1] I would like to thank prof. dr. Werner Williams-Krapp, Augsburg, for this reference.

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Referee List (DOI 10.36253/fup_referee_list)
FUP Best Practice in Scholarly Publishing (DOI 10.36253/fup_best_practice)
Joran Proot, *The economic revolution in book design that went unnoticed. The case of the Southern Netherlands, 1473–c. 1550*, © Author(s), CC BY 4.0, DOI 10.36253/979-12-215-0092-9.17, in Giampiero Nigro (edited by), *L'economia della conoscenza: innovazione, produttività e crescita economica nei secoli XIII-XVIII / The knowledge economy: innovation, productivity and economic growth,13th to 18th century*, pp. 287-314, 2023, published by Firenze University Press, ISBN 979-12-215-0092-9, DOI 10.36253/979-12-215-0092-9

produced more than 32,000 editions of books, not to speak of a vast number – and for the major part unrecorded – ephemera.[2]

Now that the problem of printing books in series was solved, a new one was waiting for a solution. As a rule, in the 'manuscript era' books were ordered first and copied out for clients subsequently. That way, production and distribution were covered from the outset. But in the 'handpress era', the new logic required that printers and publishers produced large numbers of copies for yet unknown customers. This required the development of networks and methods to inform potential buyers of the existence of books they actually had never really asked for. In the beginning, printers and publishers sometimes had to leave their workshops in search for customers (Conway 1999, 55, 57). Soon they began to advertise for their products and started to use the existing trade infrastructure and went to fairs (Coppens 2014).

2. Paper and price

While the public was being informed about the availability of books, and printers and publishers had found ways to cater them to potential buyers, still there were other difficulties to overcome. Two of them are closely connected: one is paper, another one price.

Compared to scriptoria and workshops where books were copied out by hand, shops running printing presses needed much larger quantities of writing supports. During the 'printing era', the major part of the copies was produced on paper and only a fraction still on parchment, mostly for very specific reasons. Culturally, paper had increasingly being accepted as a worthy alternative for parchment. At the latest since the last quarter of the fourteenth century, most books had been produced on paper (Schweitzer-Martin 2022, 150). In this respect, price was a first important factor. As the accounts of the city of Basel indicate, between 1402 and 1500, the price of paper dropped by about 50%, whereas the price of a hide remained more or less stable. In 1401 one hide cost the equivalent of 30 to 40 sheets of paper. In 1500, one could buy 72 to 116 sheets of paper for the price of one hide (Kälin 1974, 77). But even so, it remains a fact that in the first decades of printing paper was the greatest expense in printing (Conway 1999, 16). Also in the sixteenth century, paper remained the major cost. In Christoph Plantin's days, «[...] paper accounted for an average of 60-65 per cent of the cost of producing a book [...]» (Voet 1969-1972, II, 19). In terms of cost, paper was followed by wages (Voet 1969-1972, II, 382-384, 467).

Availability was a second factor. Parchment has always been a by-product of the food industry, which bred animals for diary and meat in the first place. As a rule, animals were slaughtered in function of that purpose, after which their hides would serve to make leather and parchment. The quantities available could never be sufficient to cover the needs of large printruns of extensive books (Schweitzer-Martin 2022, ch. 5). Paul Schweitzer-Martin has calculated that the four printshops

[2] Numbers for editions derived from the Universal Short Title Catalogue (www.ustc.ac.uk) on 3 April 2022.

active in Speyer between 1471 and 1500 used about 6 million sheets of paper to print in total some 300 different editions on an estimated printrun of 500 copies per edition (Schweitzer-Martin 2022, 152). This number clearly illustrates the importance of paper supply and the sudden upsurge in demand caused by the developping printing industry.

3. Paper thickness[3]

In this contribution, I will discuss the evolution of paper thickness of books produced in the Southern Netherlands in the period 1473 until the middle of the sixteenth century. As I will argue, changing paper thickness is one of the key elements which in all likelihood helped coping with the problem of the rapidly increasing demand for paper by the press.

Although most scholars are aware of the fact that incunabula (as books printed in the fifteenth century are called) are printed on thick paper, there is only a handfull of studies looking into this matter. It is as if anyone has ever asked the question when printers stopped using thick paper, and neither can one find in literature a definition of "thick paper". In the chapter about paper in the recently published standard work *Grundriss der Inkunabelkunde* by Wolfgang Schmitz, paper thickness is not discussed (Schmitz 2018). The chapter in question contains references to two articles by Holger Nickel from 1976 and 1980. In the 1976 article, Nickel alludes to the introduction of thinner paper: «Das Buchformat konnte nicht verkleinert werden, auch Papiersorten von geringerer Stärke verringerten den Umfang der Bände» (Nickel 1976, 484). And although he acknowledges that at a given moment books became smaller as a result of the use of thinner paper, Nickel does not go into the question when or how this happened. Four years later, Nickel makes in passing a link between the use of new sorts of paper and books becoming cheaper: «Neue Papiersorten verbilligten die Bücher, so daß ein Interessent für das gleiche Geld immer dickleibigere Werke kaufen konnte» (Nickel 1980, 322). But other than making a reference to Piccard (1967), the author remains silent.

Until recently, only a few scholars published on the topic. Two Swiss scholars jointly devoted two brief articles on the matter. The subject is also discussed in the two-volume publication of the research project *Il progetto carta*. Paper thickness is also studied by the team directed by Timothy Barrett in the context of a broader survey of handlaid paper from the fourteenth until the nineteenth century.

In a first article from 1992, Utter and Utter published a theory explaining the variation in thickness of handlaid sheets (Utter and Utter 1992). They argue that during the cyclus of making one post of paper (181 sheets), the pulp concentration in the vat gradually becomes thinner, which is reflected in thinner sheets. In addition, they identify the height of the deckle as a second factor of influence on the thickness of the sheets. Both elements have also been named by J.J.F. de la Lande in 1761, but those are not the only two relevant factors. In a comment following the article, Peter F. Tschudin rightly points out that the skill and experience of the

[3] Sections 3-6 are based on Proot 2021b.

vatman are also of great importance for the manufacture of sheets with the same weight, a viewpoint endorsed by Timothy D. Barrett (2018, 105).

In a second article, the Swiss authors discuss the variation in thickness within the handlaid sheet (Utter and Utter 1994). First, they establish that paper thickness and weight are correlated – a fact of importance for the survey discussed below in this contribution. Furthermore, they show that the handlaid sheet has thicker and thinner areas along both the short and the long edge, and that the paper is thicker on chainlines than between them. In order to make a good estimation of its thickness, they propose to measure sheets on six points (Fig. 1). The suggestion to measure different points is also made by other authors (cf. infra). Diagrams 9 and 10 in their article refer to waves in the sheet, one parallel with the short edge and the other one with the long edge (see Figures 2 and 3). Utter and Utter do not explain where these waves come from. I will come back to this later.

Fig. 1. **Six points proposed by Utter & Utter 1994, 43 (Fig. 5) to measure the thickness of a sheet of paper**

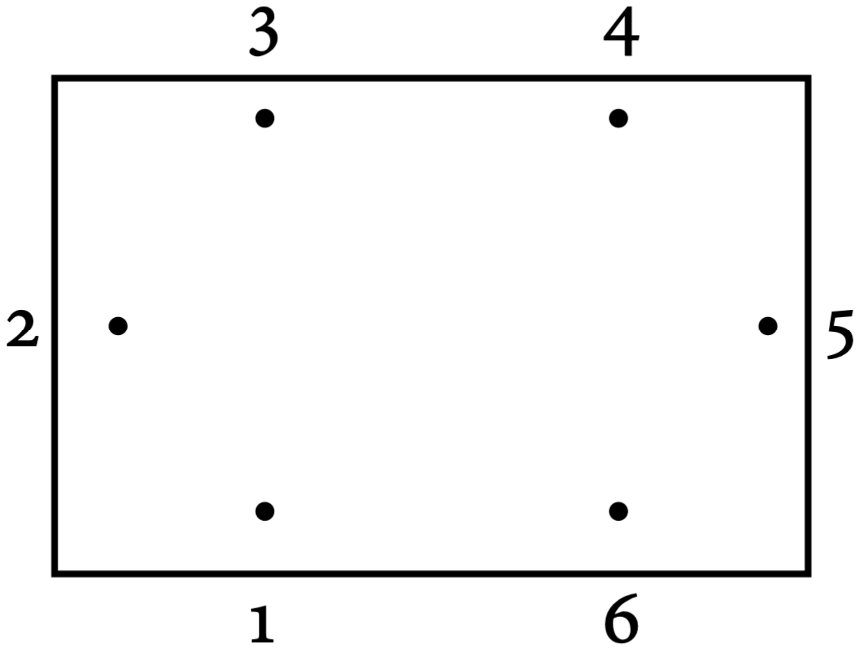


Fig. 2. **Wave detected by Utter & Utter 1994, 43 (Fig. 9) in the upper and lower long edges of a sheet of paper. The abbreviation «St». (German: «Steg») indicates the position of the ribs of the mould**

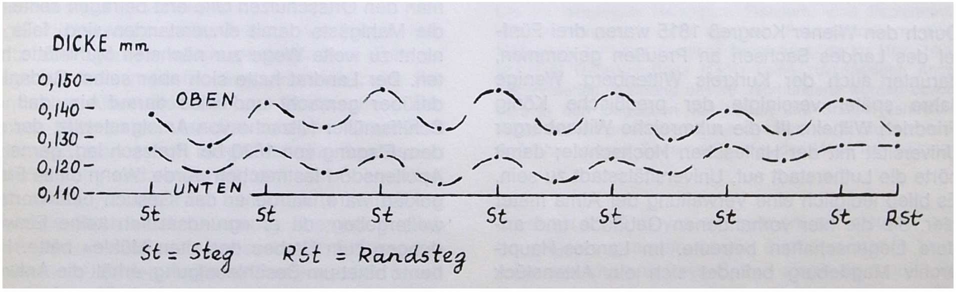
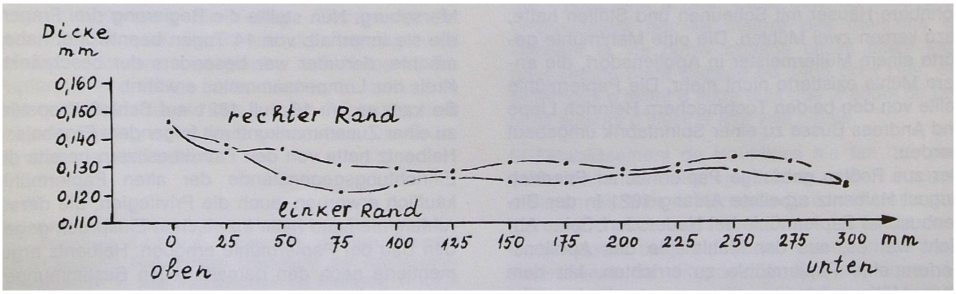
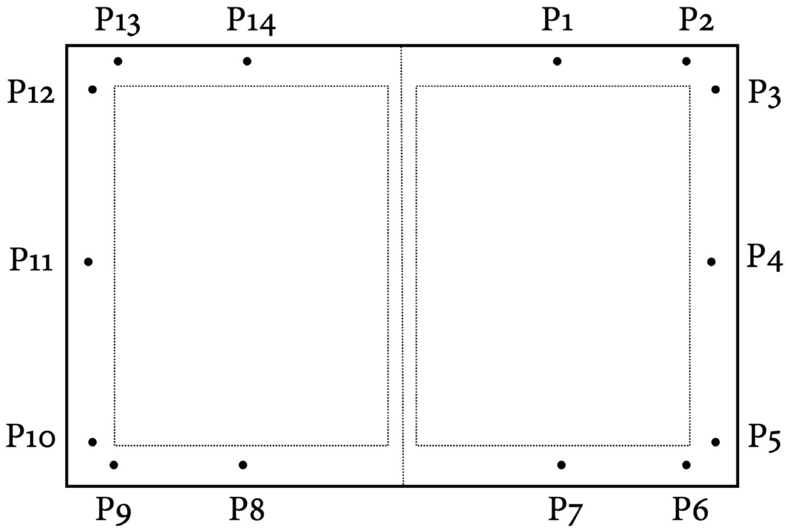


Fig. 3. **Wave detected by Utter & Utter 1994, 43 (Fig. 10) in the left and right short edges of a sheet of paper. «Rechter Rand» refers to the right edge, «linker Rand» to the left edge of the mould**



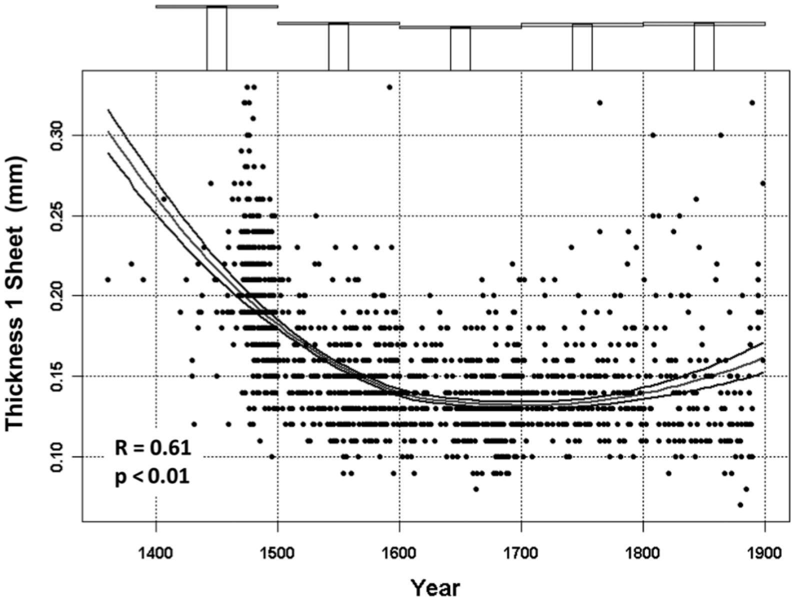
The researchers of *Il progetto carta* published two volumes on the late-medieval paper and about incunabula (Ornato et al. 2001). They discuss, amongst other things, different formats, the colour (whiteness) of paper and its thickness. Their point of departure is that the sheet is a three-dimensional structure with two flat faces. They measure the thickness of sheets on 14 different points, which usually return 14 different values (Ornato et al. 2001, I, 44; Fig. 4). They argue that these differences are (in part) the result of a certain degree of *grumosità*, impurities in the pulp caused by coagulation of fibres: «La grumosità della carta medievale – e più in generale le impurità in essa presenti – non ha suscitato un enorme interesse presso gli storici del manufatto. Solo Dard Hunter – che le definisce peppered appearance – ne indica brevemente le cause: i grumi sono dovuti all'intrecciarsi delle fibre di cellulosa nella sospensione» (Ornato et al. 2001, II, 103). Whereas the values between points which lay close to each other show positive correlations, points between which there is a great distance, show negative correlations. This observation is left without further explanation (*ibidem*).

Fig. 4. **Location of the fourteen measuring points on a sheet of paper used by Ornato et al. 2001 (I, 44)**



In their survey *Non-destructive analysis of 14th-19th century European handmade papers*, Barrett, Ormsby and Lang try to figure out how handlaid paper changed in the course of five centuries. For this purpose, they studied the quality of 1,578 historical samples of European sheets. In addition to colour (whiteness), their focus is on sizing practices with gelatine (Barrett et al. 2016). With several sophisticated measuring tools, they are able to trace elements such as calcium and iron in the paper. Iron is linked to a darker paper colour and has its origin in polluted water used during the production. This metal has a negative impact on the paper quality. Furthermore, the researchers have found that the quantity of gelatine for sizing is reduced significantly in the sixteenth century compared to the fifteenth century. At the same time, they find that paper gradually becomes thinner, an observation which is confirmed through the use of a micrometer with a presicion of 0.01 mm (Barrett et al. 2016, 106-108). In order to cope with the «natural variation in paper thickness in a single book», the scholars measure ten subsequent leaves (Barrett et al. 2016, 103), a phenomenon of which Barrett, who is a papermaker himself, is very well aware. In this study, neither the origin of this variation is explained, nor is the measuring methodology discussed in detail. We can only assume that all different bibliographical formats were treated in the same way. Graph 10 in this study is a scatter plot showing the paper thickness of individual sheets, along with a regression line. The scatter plot in Graph 11 is based on values for 10 sheets. (See Figures 5 and 6.) The regression line shows values which are systematically lower than those on Graph 10, a difference which remains unexplained. Based on our own research (Proot 2021b), we gather that the difference is due to the so-called compression effect (cf. infra).

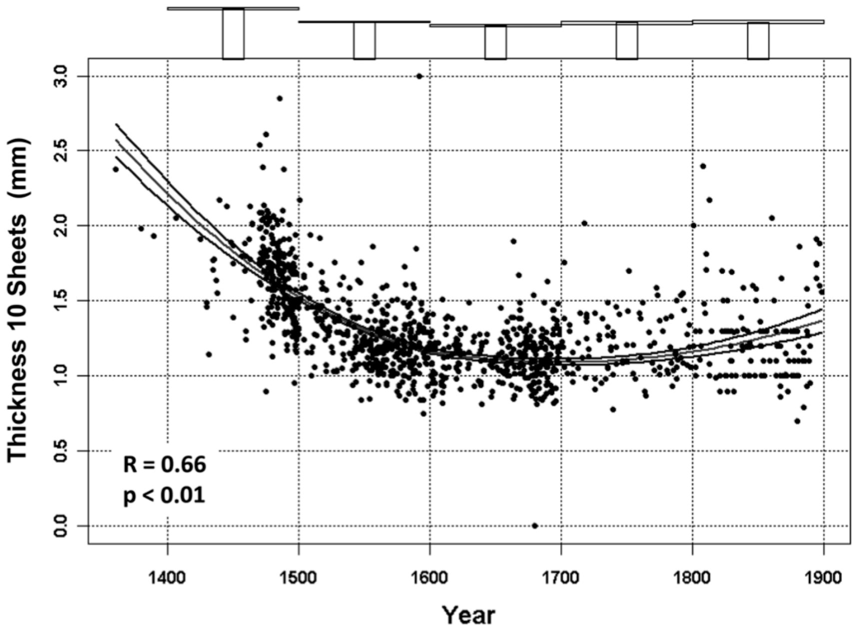
Fig. 5. **Graph 10 taken from Barrett et al. 2016, 107**



Note: «The thickness of specimens is shown according to year [...]. The discrete levels in the vertical axis result from the minimum increments on the micrometer. The decrease in thickness was statistically significant over the first three periods in the tabletop plot».

Barrett and his colleagues suggest that the first printers consciously used papers with a structure, colour and dimensions emulating parchment (Barrett et al. 2016, 110-111). By doing so, they probably aimed at creating objects with a look and feel close to traditional books (compare Proot 2017, 21-22). For the productions of thick sheets mills required much pulp, what has a direct impact on the price. Papermakers lowered the price of paper by making it thinner and by using less sizing. Curiously, the researchers also link thicker paper with lower quality (Barrett et al. 2016, 118-119), which they explain by a faster production of the pulp. I find this a puzzling statement; probably there are other elements involved.

Fig. 6. **Graph 11 taken from Barrett et al. 2016, 108**



Note: «The discrete micrometer increments are less apparent in this plot of the thickness of the specimen together with the following 9 sheets in the book. [...] The tabletop confidence intervals indicate a statistically significant decrease in thickness over the first three periods». The authors do not explain the difference in thickness between Graph 10 and Graph 11. Based on Graph 10, one would for instance expect that the regression lines at 1500 would intersect at a value somewhere between 1.6 and 1.8 mm for 10 leaves, but the average value is lower.

Five years ago, I started measuring paper thickness of early modern books from the Southern Netherlands in the context of an exhibition about typographical features of incunabula and postincunabula (Proot 2017). Two years later, I continued this research together with prof. dr. Wolfgang Jacquet, a Belgian statistician (Vrije Universiteit Brussel), and dr. Paul Schweitzer-Martin, a German book historian (University of Munich). Much of the findings presented here below are the result of our discussions and try and error.

4. Relevant aspects of the handlaid-paper production in the West

It is not a simple task to establish the thickness of handlaid paper produced in the handpress era. In contrast to modern, machine-made paper, the morphology of handlaid paper is not plane but fairly complex. A better understanding of the morphology requires a discussion of the raw material to produce paper, the construction of the mould, paper making and wholesale practices.

For about eight centuries, the process of paper making in Europe basically remained unchanged (Loeber 1982, 4-5). Handlaid paper, that was made in Spain from the eleventh century and not much later in Italy and elsewhere on the continent, is a by-product of clothes and fabrics, which were woven with natural, celluloid-rich fibers of vegetal origin (Loeber 1982, 4). For the production of paper served mainly hemp and linnen, but also other fibers were used, such as cotton (Barrett 2018, 4-28). The raw materials were collected by old-cloths-men and then sorted according to quality. Buttons and other foreign elements were removed from the rags, which were then cut to pieces and washed. Then the rags were soaked and underwent retting (fermentation or putrefaction). To reduce the loss of fiber during this process, quicklime or chalk could be added to the mix. This also added an alkaline reserve to the resulting paper, which had a positive effect on its preservation (Schmitz 71; comp. Barrett 2018, 25). After these chemical processes the stuff was subsequently further reduced mechanically by water-wheel powered stamper beaters to individual, softened, cellulose fibers. Constant washing also bleached and plasticized the fiber (fibrillation). As a result, fine fibrils raised from the main fiber surface (Barrett 2018, 24), which later on advanced the 'closing' of the sheet during the papermaking process. The resulting stuff was mixed with water in a vat. Any impurities in the stuff result in impurities in the paper, such as coagulating stuff and knots, in Italian also called «grumosità» (Ornato et al. 2001, II, 103), which can easily detected by holding up the paper against the light or by measuring thickness. In my experience, such bulges and swellings in the paper appear quite often in fifteenth-century paper used to print books in the Southern Netherlands, and much less so in copies produced later. This suggests that production methods may have been refined gradually. Between 1650 and 1680, the Dutch developed the so-called «Holländer», a wind-powered machine which reduced rags to fibrillated fibers (Barrett 2018, 25-27). The use of this machine no longer required preparatory retting.

In Europe, a rigid mould with a wire cover was introduced around 1250 and remained in use until the end of the modern era. It consisted of a rectangular frame the long sides of which were connected by ribs running parallel to the short sides about one inch apart (Loeber 1982, 5). Thin metal wires (until around 1700 usually made of copper) were stretched above the ribs. These lines are known as chain lines. One extra wire was added on both sides of the frame to strenghten the construction. These lines are called «tranchefiles», also known as «water-bar lines», «water-bar wires» or «suction-bars» (Gaskell 2006, 61; Loeber 1982, 41; Labarre 1952, 327, s.v. *water-bar*). Placed on top of chain lines and tranchefiles, and perpendicular to them, are the so-called wire lines, metal bars with a gauge of about 0.65 mm standing about 0.35 mm apart (Loeber 1982, 20). This construction forms a sieve holding the stuff from the vat while the water runs through it. From the late thirteenth century, mould-makers sew a thin metal figure made of a thin copper or silver wire onto the mould covering, leaving a watermark in the paper. In the handpress era, watermarks can usely be spotted in the middle of the upper or lower half of the sheet when held portrait-wise against the light. In the middle of the other half often appears, from the late fifteenth century, a secondary mark or so-called «countermark», which becomes more frequent from the sixteenth century (Loeber 1982, 49; Labarre 1952, 60, s.v. *countermark*).

For making paper, the vatman places a deckle on top of the mould, which prevents the water and stuff from running off the sides of the mould (Labarre 1952, 70, s.v. *deckle*). It is the dimensions of the deckle which define the height and width of the sheet, and which, to a certain extent, help to make thinner or thicker paper. But in the end, it is the experienced vatman who will define the thickness of the paper by taking on extra stuff onto the mould or throwing off excess stuff during the papermaking process. Stuff piling up against the edges of deckle will result in the characteristic irregular and thicker «deckle edges» of the handlaid sheet.

The quality of the paper depends to a great extent on all the steps preceding the actual sheet forming. But the work of the vatman, the coacher, and the layer, too, are essential and can leave unwanted traces on the final product if they do not perform well. The vatman puts the deckle on top of the mould, which he holds with his hands on the short edges, with the long sides parallel to his chest. Then he dips the mould into the vat, brings it up, and then controlls the weight by throwing off or taking on stuff. As de la Lande described in 1761 with great precision, the vatman distributes the stuff evenly on the mould by shaking it with controled gestures from left to right and from right to left («*promener*»), and then in the other direction, pushing it away from him and pulling it back to him («*serrer*»). Finally, the sheet is "closed" with a specific shake («[...] *enverger la feuille, c'est-à-dire, à la fixer & à l'arrêter*», cf. de la Lande 1761, §125), binding and fixing the fibers drifting about in all directions, which solidifies the structure. During these movements, the water runs through the sieve. The ribs of the mould accelerate the evacuation of the water, locally causing minuscule heaps of pulp, resulting in 'shadows' parallel to the chainlines when looking at the sheet against the light (de la Lande 1761, §84). These 'waves' of thinner zones in between chainlines and thicker zones immediately next to the chainlines have been described by Utter and Utter (1994). After the closing of the sheet, the vatman removed the deckle, pushed the mould to the coucher, and repeated all actions with a second, nearly identical mould (the so-called twin) to form a second sheet.

The coucher transferred the sheet from the first mould onto a damp woolen felt with a rolling motion. This action results in a rough mould side of the sheet, which is marked by the metal wires pressing into the waterleaf sheet, and a so-called smoother felt side. The difference can often easily be sensed or visually detected with raking light. The sheet is then covered by a second felt, on which is couched the following sheet and so on, until a 'post' of felts and sheets is ready to be pressed under a massive wooden press for further dewatering (Barrett 2018, 31). When the post is dry enough, the layer cautiously strips the still vulnerable sheets from the felts for further drying and repeated pressing in smaller packs, an operation adding more smoothness to the surfaces of the sheets (Barrett 2018, 32). Afterwards, the sheets were taken to the drying room, where 'spurs' of three to eight sheets at once were hung over horsehair or cow's hair ropes coated with beeswax (Barrett 2018, 32). Sometimes, the ropes left a folding trace in the middle of the sheet. During the drying process, the paper shrank, depending on the season, up to 4% in length and 2% in width (Loeber 1982, 41). Drying was followed by sizing, which in Europe from the fourteenth century was usually done with gelatine. Without this treatment the sheets reacted as blotting paper. In addition, gelatine also added considerably to the strenght of the sheets. Hereafter, the paper had to dry again and was then flattened and polished on a marble stone or hammered on an iron plate. Around the middle of the eighteenth century, sometimes calenders were used to flatten the sheets (de la Lande 1761, §117).

After a quality control, the paper was packed for the wholesale market in reams (units of 500 sheets) and bales (10 reams). In retail, paper was sold per hand (24 or 25 sheets). Each sort was defined by its dimensions and minimum weight, which was set per ream (de la Lande 1761, §115). Fluctuations in weight were tolerated, but always between well established limits. Sheets which did not meet the standards were discarded during the production process, which contributed to a certain degree of homegeneity among paper of a specific quality. For printing, paper has to have a minimum thickness and strenght in order to prevent type piercing through the sheet. In addition, paper had to be opaque enough so that the printing on the verso would not bleed through and disturb reading. In some areas paper for the printing industry remained unsized until after printing, but this was not the case in the Southern Netherlands. In the incunabula period, however, gelatine levels for sizing printing paper were lowered to make it easier to print on (Barrett et al. 2016, 110-111). Incidentally, this also reduced the production cost of paper.

5. The morphology of handlaid paper

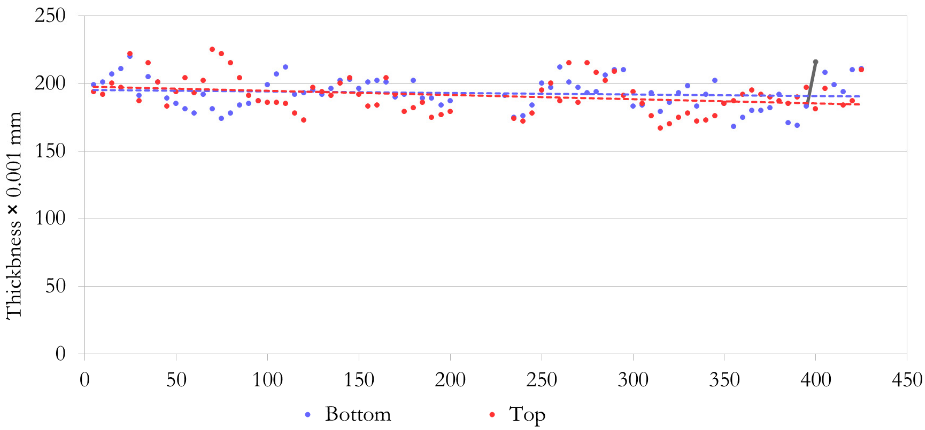
Each handlaid sheet of paper is unique as a result of the composition of the pulp, the characteristics of the mould, and the different stages of the actual papermaking process carried out by the different agents involved. In contrast to modern machine paper, handlaid paper has no direction in which it feeds, and neither it is perfectly plane. Handlaid paper has the structure of an egg carton, or of two intersecting chains of mountains and valleys, one of which runs parallel to the short edge and the other one parallel to the long edge of the sheet. This results from the *promener* and *serrer* of the vatman, movements generating two so-called perpendicular standing waves, now neutralizing and then amplifying each other. Some scholars have indicated the hills and dales running parallel to the chainlines (the short edge of the mould; Tschudin 2002, 51-52), but if one looks closely at a handlaid sheet against the light, it is obvious that there are also hills and dales running running paralled to the waterlines, so perpendicular to those running parallel to the chainlines.

In addition, sheets are usually slant in two dimensions, in height as well as in width. The near side of the mould, closest to the vatman's body, is usually thicker, because he usually holds the mould at an angle with the far side up. As a result, the pulp slightly accumulates at the near side. But in the other dimension, one side is also thicker than the other one. This is linked with the fact that everyone has a dominant arm, which naturally carries more wheight than the other one. As a result, the pulp naturally flows down from one side to the other one.

Both phenomena, of the intersecting mountains and valleys, and of the slant in two directions, can be detected through measuring handlaid sheets with a precision instrument (Graph 1).

At any stage the papermaking process, mistakes will also leave their traces in the structure of the sheet. This can involve a drop of water which inadvertently fell on the mould; a thumb of the coucher placed on the still wet sheet, a sudden displacement during couching, an uncautious handling during the drying process, improper polishing of the sheet, etc (Barrett 2018, 113-120). In addition, printing with moveable type leaves dent on the paper, which is usually not completely pressed out by the binder. And when rebound, sheets are sometimes washed out, and sometimes pressed again, individually or in quires. This is sometimes done so thoroughly, that nearly every aspect of natural handlaid paper is removed.

Graph 1. **Thickness measured every five mm on a double leaf of an incunabulum showing the wave caused by the «promener» by the vatman**



Note: Thickness (in 1/1000 mm) of fol. [A]5 verso-6 recto, bottom and top, copy Liège BU XV.B.185

6. Measuring handlaid paper

With these facts in mind, it should be clear that it is impossible to establish "the" exact thickness of a handlaid sheet of paper. Depending on where one lands on a sheet with a measuring instrument, one will find a different result. The thickness of a single sheet could therefore never be correctly defined by a single value, but it should be rendered by a large enough collection of values, from which a range, an average value, and a median value can be derived mathematically. In order to have a reliable estimate of both mean and standard deviation on the level of a single sheet, limiting the effect of undersampling larger values due to probability concentration about the mean on the standard deviation, a sample of at least 30 points randomly distributed over the entire sheet would be required.

The precision instrument used for this survey, however, does not allow for this method. I used a professional instrument Käfer type FD 50 C with a precision up to 1/1000th of a millimeter.[4] This instrument has a number of limitations. It can only measure up to maximum 50 mm away from the edge of a sheet, which means that only the outer margins are in reach. It cannot measure objects thicker than 12.5 mm. The measuring surface is round and has a diameter of 10 mm, which means that the instrument can only detect the highest point under that surface. As a result, the thinnest spots on the sheet will remain invisible and therefore unknown. On the other hand, the instrument is calibrated, and its maximum deviation is negligible for this kind of research. It is easy to manipulate, and tests with a second, identical instrument proof that the results are very reliable (Schweizer-Martin, Proot & Jacquet 2023 [in press]).

When measuring leaves in early modern books, one has to avoid some obvious areas. Deckle edges, as well as defects in the paper such as tears, holes, and knots will evidently result in ouliers. If possible, one should also avoid the printing area (dent) and stay in the blank margins, but in small bibliographial formats of books (octavo and smaller), this is not always possible.

In 2021, I developed a method to measure the thickness of sheets of early modern folio books (Proot 2021b). In the folio format two pages are printed on each side of a sheet of paper, in total four pages on one sheet recto/verso. The sheets are folded once and assembled to form quires, which are usually bound. After a thorough analysis of different series of measurements on three copies of the same edition, the following conclusions were made.

- As a rule, it is possible to obtain a very good idea of the 'overall' thickness of a sheet in folio books selecting "only" 14 evenly spread measuring points in the margins for a limited number of sheets, e.g., 10 (see Figure 7).
- In most cases, it is even possible to detect the thicker 'short edge' and the thicker 'long edge' of the sheet based on 14 evenly spread measuring points in the margins.
- As a rule, sheets landed randomly on the press, with the watermarks oriented at random (upright, upside down, in the left half, in the right half of the sheet). It is very likely that this was done on purpose to prevent skew book blocks.
- Statistically, seven selected measuring points on one side of a sheet – one leaf in a folio book – also render a very good idea of the thickness of the sheet to the order of magnitude of the difference in thickness between the thinner and the thicker side of the sheet. For the distribution of these points, see Figure 7.
- The thickness of one point measured right in the middle of the short edge (the so-called midpoint, in the outer margin) gives a very good indication of the order of magnitude of the average value of six points distributed evenly over the margins of a leaf (see Figure 7).
- The combined thicknesses of the midpoint in the outer margin measured on ten subsequent leaves is higher than the thickness of that point measured on a stack of ten leaves measured at once. This results from the so-called compression effect, whereby stacked leaves ajust to each other so that mountains and valleys

[4] For the technical specifications, see: https://praezisionstools.de/mwgpt/dicke/skd001/Messuhr_KA20054-c.html#details; see also https://praezisionstools.de/kataloge/mwgpt_dicke.pdf at page 25 (last consulted 8 April 2022).

accomodate like spoons (compare the waves on Graph 1). The difference in thickness observed in the testcase is about 9%.
- Depending on the specific characteristics of the paper, the compression effect can be reversed when a stack of leaves measured at once becomes too voluminous. At a given moment, it becomes rigid and stiff, which results in higher values than one would obtain when leaves are measured individually and subsequently values are added up.
- The thickness of leaves in books which have been rebound, can be reduced by 10% and more compared to books in their original binding.

From this testcase, we retain the following. If we want to compare values across books, we should always use the same method to measure the thickness. Measures should be taken at the same spot, always on the same number of subsequent leaves, and always in the same way: either each leaf individually, or the complete stack of leaves at once. For the survey discussed below, I systematically applied the same measuring method.

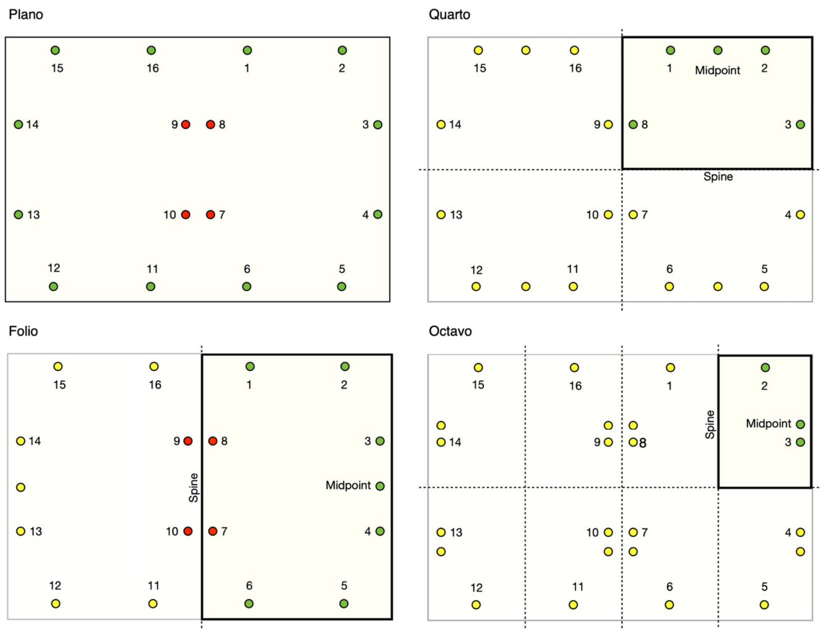
7. Comparing thickness in different bibliographic formats

Weaponed with this knowledge, I recently developed a method to compare paper thickness through different bibliographical formats, in casu, folios, quartos and octavos. These three formats are the most important ones for books produced in the Southern Netherlands which were collected by institutional libraries (Proot 2021a, 243-244). For each format, a number of measuring points is selected in such a way that they always have a number of measuring points in common with the other formats. For folios they include two points in the upper and lower margin of the leaf, and three points in the outer margin. For quartos five points are measured, i.e., one in the upper and the lower margin, and three in the outer margin. In the case of octavos, three points are measured: one in the upper margin and two in the outer margin. All three formats directly have both points 2 and 3 in common (Figure 7).

The points in green are directly in reach for measuring. In books, sheets are folded to form gatherings, so when 10 leaves in a folio book are measured at once, point 1 corresponds with point 16, point 2 with point 15 and so on. The points measured indirectly are marked with yellow for each bibliographical format. Only in the folio format, four points in the middle of the sheet are out of reach (point 7, 8, 9, and 10, marked in red). They are located next to the spine.

Between 1 and 9 April 2022 in total 379 books produced in the Southern Netherlands in the holdings of the Royal Library in Brussels were measured this way: 87 folios, 201 quartos and 91 octavos. The temperature in the reading room fluctuated between 19.3°C in the morning to 24.5°C in the afternoon, and along with it the relative humity slowly dropped from 44% in the morning to 28% in the afternoon. The effect of these fluctuations on the paper thickness of handpress books has not yet been studied. Only 15% of the copies consulted was found in its original binding (58), and in many cases those copies, too, underwent at one point or another treatment (e.g., rebacking, new flyleaves). The majority of the copies was rebound in the nineteenth or twentieth century, some probably even more recently. It was not yet possible to consult the files about the restoration work and further to detail the exact nature of the interventions.

Fig. 7. **Measuring points on a full sheet, a folio, quarto, and octavo leaf**



From a previous study, we know that rebinding may have a serious impact on paper thickness (Proot 2021b). Only six incunabula were found in their original binding, each time two per decade between 1471 and 1500. This means that the majority of the values found for this period probably are rather on the low side. In contrast, seven in seventeen copies from the period 1551-1560 probably were never rebound, implying that the numbers for this decade may be rather on the high side compared to the rest of the dataset. Unfortunately, the different subsets are not large enough to perform statistical tests to verify potential correlations.

Tab. 1. **Paper thickness of 10 leaves measured at once at points 2 and 3 (1/1000 mm) (April 2022)**

Decade	Format	Copies	Thickness at point 2	Thickness at point 3
1471-1480		*34 (original binding: 2)*	*1733.4*	*1686.1*
	Folio	27	1765.9	1682.5
	Quarto	7	1608.1	1700.0
1481-1490		*63 (original binding: 2)*	*1446.1*	*1453.2*
	Folio	27	1506.6	1473.2
	Quarto	33	1405.9	1448.4
	Octavo	3	1344.3	1325.0
1491-1500		*28 (original binding: 2)*	*1319.4*	*1323.5*
	Quarto	19	1312.3	1315.9
	Octavo	9	1334.4	1339.4
1501-1510		*52 (original binding: 10)*	*1254.7*	*1274.1*
	Folio	7	1485.3	1406.7
	Quarto	28	1279.6	1307.6
	Octavo	17	1118.7	1164.1
1511-1520		*72 (original binding: 8)*	*1252.3*	*1256.4*
	Folio	12	1368.0	1275.8
	Quarto	56	1231.8	1259.6
	Octavo	4	1192.0	1153.5
1521-1530		*50 (original binding: 9)*	*1216.6*	*1240.4*
	Folio	7	1380.6	1339.3
	Quarto	34	1174.0	1214.6
	Octavo	9	1250.1	1261.0

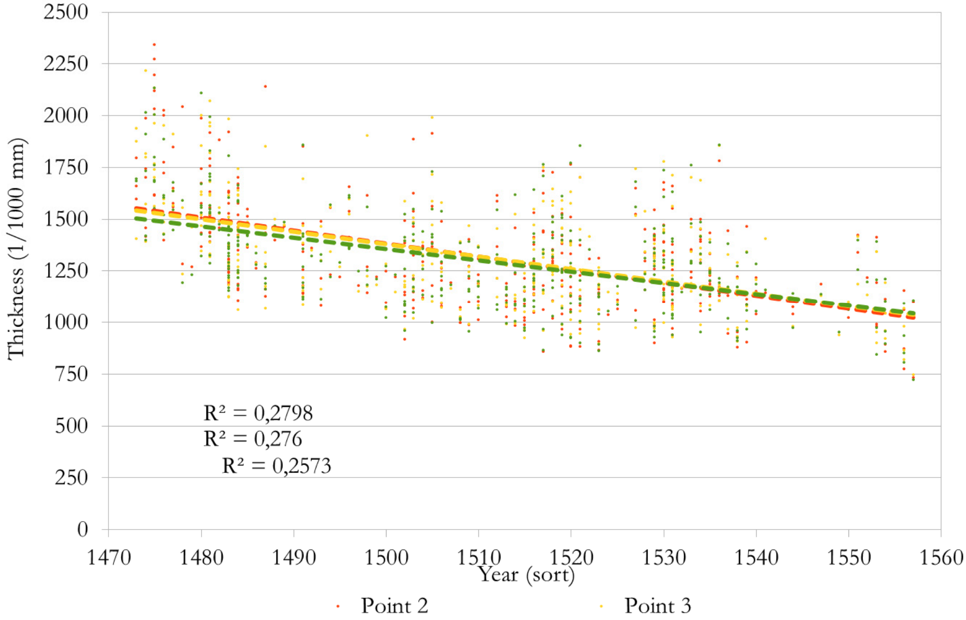
1531-1540		*56 (original binding: 16)*	*1219.6*	*1232.2*
	Folio	7	1387.3	1383.7
	Quarto	19	1243.1	1289.2
	Octavo	30	1165.7	1160.7
1541-1550		*7 (original binding: 2)*	*1088.0*	*1104.0*
	Quarto	1	1143.0	1405.0
	Octavo	6	1078.8	1053.8
1551-1560		*17 (original binding: 7)*	*1066.7*	*1052.8*
	Quarto	4	1229.3	1214.0
	Octavo	13	1016.7	1003.2
Total		*379 (original binding: 58)*		

Graph 2 shows the distribution of the thickness measured on point 2 and 3, and on the midpoint. While the trendlines for point 2 and 3 almost completely overlap, the trendline for the midpoints (in green) starts a little bit lower and ends just a tiny bit higher on the graph. This may have to do with the position of the midpoint, which is different for folios – which is the dominant format in the period 1471-1480 –, quartos – dominant between 1481 and 1530 –, and octavos (compare Figure 7).

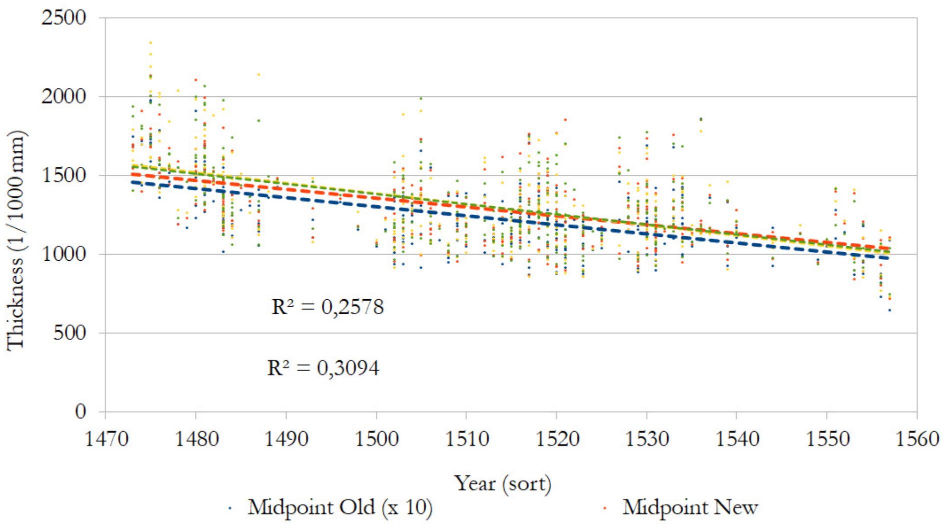
For 312 copies of the above described dataset, we possess additional data collected back in 2017, collected with a different, less precise electronic caliper. In contrast to the Käfer model described above, this caliper did not work with a spring, but had to be closed by hand. Because it is impossible to exercise each time exactly the same pressure, this must have influenced the results. In addition, this caliper measured only up to 1/100 mm.[5] Graph 3 compares the values obtained with the caliper used in 2017, and those from April 2022. The results from 2017 are multiplied by ten, so that both series can be plotted on the same scale (1/1000 mm).

[5] Unfortunately, on 1 November 2017 Polish customs confiscated this instrument when I wanted to board the airplane for Brussels, as they considered it a potential offensive weapon. Therefore I cannot give any more details about it.

Graph 2. **Thickness of points 2 and 3, in addition to that of the midpoints (in 1/1000 mm), taken from 379 copies produced in the Southern Netherlands between 1473 and 1557 (April 2022). Each time 10 leaves were measured at once**



Graph 3. **Thickness of midpoints measured in 2017 (Old) and in 2022 (New), using different calipers.**



For the period 1471-1560, both trendlines for midpoints run parallel, thus confirming the trendlines plotted on Graph 2 for measuring points 2 and 3. The values of the midpoints registred in 2017 are systematically lower than the values measured in April 2022. The difference between both values calculated on the entire dataset of 312 records is 4.3%. This gives a handle to interpret the values in Table 2, especially those from the second half of the sixteenth century, for which extra datacollecting according to a reliable method and with a precision instrument is still wanting.

Tab. 2. **Average paper thickness of 10 leaves on midpoint (1/100 mm) (2017)**

Decade	**Format**	**Copies**	**Thickness on midpoint (1/100 mm)**
1471-1480		*69*	*157.6*
	Folio	60	158.4
	Quarto	9	152.4
1481-1490		*128*	*139.6*
	Folio	52	148.0
	Quarto	67	135.4
	Octavo	9	122.0
1491-1500		*32*	*124.5*
	Folio	3	148.3
	Quarto	20	126.0
	Octavo	9	113.0
1501-1510		*78*	*121.2*
	Folio	9	128.1
	Quarto	44	124.3
	Octavo	25	113.2

1511-1520		*95*	*120.0*
	Folio	19	123.1
	Quarto	69	120.1
	Octavo	7	111.0
1521-1530		*69*	*113.6*
	Folio	10	122.5
	Quarto	38	110.6
	Octavo	21	114.7
1531-1540		*83*	*115.2*
	Folio	9	140.1
	Quarto	18	122.2
	Octavo	56	109.0
1541-1550		*31*	*101.2*
	Octavo	31	101.2
1551-1560		*95*	*104.5*
	Folio	6	123.7
	Quarto	23	104.4
	Octavo	66	102.8
1561-1570		*29*	*106.3*
	Folio	5	110.2
	Quarto	1	117.0
	Octavo	23	105.0

1571-1580		*26*	*117.2*
	Folio	8	116.9
	Quarto	6	139.3
	Octavo	12	106.3
1581-1590		*16*	*116.1*
	Folio	4	111.8
	Quarto	4	131.3
	Octavo	8	110.8
1591-1600		*21*	*118.7*
	Folio	2	121.5
	Quarto	4	117.3
	Octavo	15	118.7
Total		*672*	

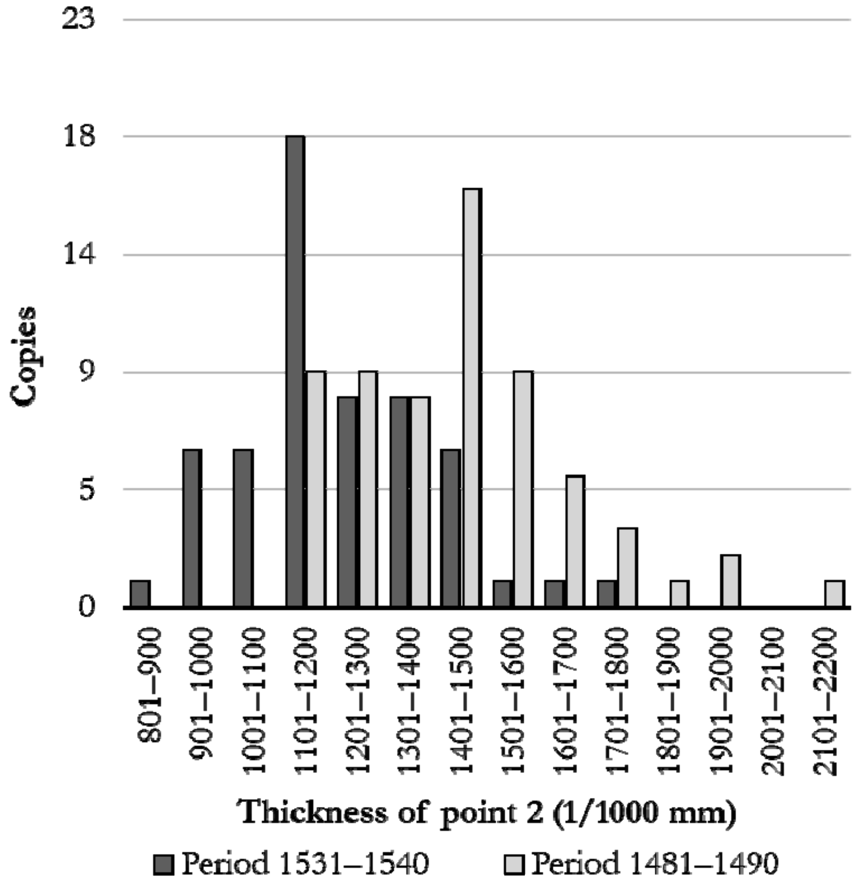
Although the subsets for the period after 1560 are not very substantial, the average thickness goes up again, from about 1.06 mm for 10 leaves in 1561-1570 to about 1.18 mm in the last decade of the sixteenth century.

Another observation one may make, is that in a given decade the paper of folios is, on average, often thicker than that in quartos, which in turn is often thicker than that of octavos. In the period 1481-1490, the average thickness of point 2 for folios is about 1.50 mm for 10 leaves against 1.41 mm for quartos (see Table 1). In the period 1501-1510, the average thickness of point 2 for quartos is about 1.28 mm for 10 leaves against 1.12 mm for octavos, and one decade later, the numbers are about 1.24 mm for quartos against 1.17 mm for octavos. This seems to be confirmed by most values in Table 2, but more data are required to confirm this trend statistically.

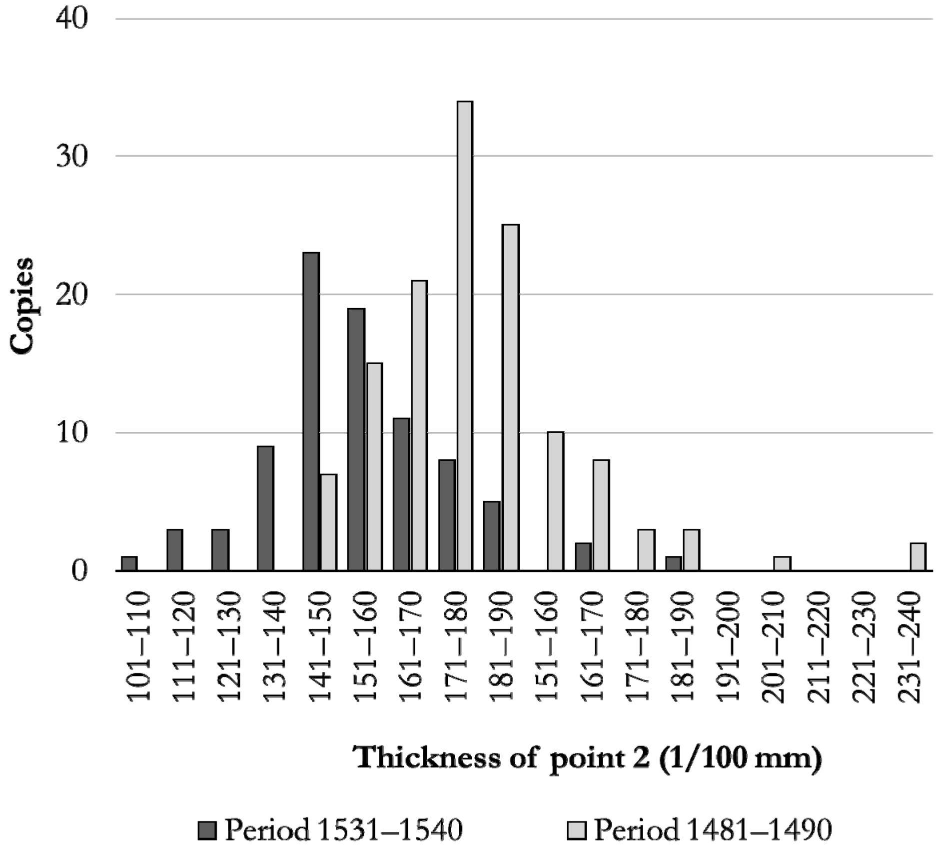
The coefficients of determination (R^2) of the trendlines on both scatterplots Graph 2 and 3 have values between about 0.2578 (value for midpoints measured in April 2022) and 0.3094 (midpoints recorded in 2017), which means that time (x-axis) explains only part (about 25 to 30%) of the observed variance (Blondé et al. 2012, 138-139). The R^2 values reported are relatively low but statistically significant. They can be said to be weak. However, the scatterplot does not provide indications that would motivate a higher order or complex modelling. In itself, the importance is the identification of a trend. This is a first step and further investigation is needed in order to identify influencing factors through more sophisticated sampling and additional information in combination with advanced modelling. Influencing factors may be, amongst other, bibliographical formats and different sheet sizes.

The distribution of the individual values on Graphs 2 and 3 indicates that there is a fairly wide choice in paper thickness. Graphs 4 and 5 give an overview of this distribution for two decades, for which subsets in both Table 1 and 2 hold enough datapoints to draw a usefull picture. Graph 4 is based on the actual thickness of 10 leaves taken on point 2 in April 2022, for the period 1481-1490 and fifty years later, in 1531-1540. Graph 5 shows data from the same decades, but they are taken from measurements of midpoints recorded in 2017.

Graph 4. **Distribution of thickness taken on point 2 (1/1000 mm) of copies published in the period 1481-1490 and 1531-1540 (April 2022)**



Graph 5. **Distribution of thickness taken on the midpoint (1/100 mm) of copies published in the period 1481-1490 and 1531-1540 (2017)**



Both Graphs 4 and 5 show that in both decades printers had access to paper of different thicknesses. This seems to be confirmed by Figures 5 and 6, taken from the survey by Barrett et al. in 2016. In the period 1481-1490, the paper thickness varies between 1.10 mm (for 10 leaves) and 2.20 mm (Graph 4). Fifty years later, the thickness for 10 leaves ranges between 0.80 mm and 1.80 mm. In the first period, there is a clear preference for rather thick paper: 52% of the copies is printed on paper with a thickness of 1.30 to 1.60 mm for 10 leaves (data from April 2022). Half a century later, 57% of the paper has a thickness of 1.00 to 1.30 mm for the same amount of leaves (April 2022). For the first period there has no use of extremely thin paper been recorded, and fifty years later, extremely thick paper seems to have fallen out of use. What both Graphs 4 and 5 proof, is that, at all times, paper of a wide variety of weights was available, and that printers always had – to a certain degree – options.

8. Discussion

The notion that printers always had a choice between thinner or thicker paper, is essential, because it makes clear that what we can observe in the books and see on the graphs is not the result of mere chance. Well on the contrary, the selection of this or that paper stock was a deliberate decision, and thus meaningful.

The selection of thick, and in some cases, extra thick paper in the beginning of the printing press, suggests that printers in the Southern Netherlands opted for a canvas which look and feel was quite close to that of parchment. The paper thickness corresponded fairly well with that of parchment (Proot 2017, 21), and as Timothy D. Barrett has pointed out, the heavily sizing with gelatine in the beginning of the handpress era also added to the resemblance between the two materials (Barrett 2013, 120). From a cultural point of view, this makes a lot of sense. Certainly in the beginning of the handpress period, printers and publishers mainly produced large and impressive books for audiences which were used to a certain degree of quality and luxury. Hence the dominance of folios during the first years of printing, also in the Southern Netherlands. Printers and publishers for this public would not want to make their books look cheap. The look and feel of all aspects had to correspond as much as possible with prevailing standards. It has often been pointed out that the first generations of printers wanted to 'imitate' manuscript books. What actually happened, is that the only thing they changed was the way the main text was put on the canvas. This was no longer executed by clecks and copyists, but mechanically with type and presses. All other aspects of the layout remained the same; like manuscrips printed books remained only half-products until rubricators and illuminators had completed them.

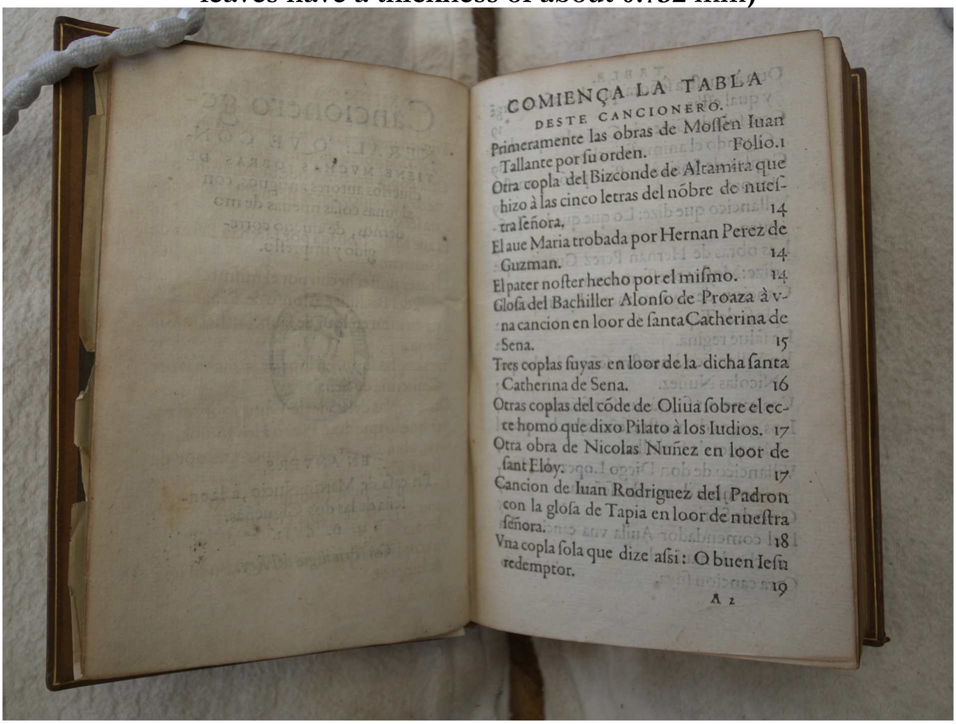
When the public had more or less accustomed to the new books, slowly but surely one aspect after the other one underwent change in order to make books cheaper and better. I have described different aspects of this process in a number of publications (Proot 2017; 2021a; 2022). The most visible transitions include the growing importance of smaller bibliographical formats (first quarto, then octavo, and smaller formats), the increase of type areas and the reduction of white margins, the development of smaller type, and the substitution of navigation aids in colour by printed paragraph marks, printed larger and ornamental initials, and the functional use of white to add structure (indentation, white lines). Amongst these phenomena, the overall reduction of the paper thickness between 1473 and the middle of the sixteenth century is probably one of the most important changes. Depending on the criteria, the average thickness of the paper used to print books in the Southern Netherlands dropped 34 to 38.5 per cent in 80 years. Given the fact the major part of the early books in this survey have been at least once rebound, this number is probably an underestimation.

Paul Schweitzer-Martin has observed the same trend for Speyer in the period 1471-1500. Based on a survey of 200 copies, he also found that printers used at all times paper of different thicknesses, and that the average thickness diminished from about 2.1 mm for 10 leaves in 1571 to about 1.6 mm in 1500 (Schweitzer-Martin 2022, 170, Abb. 47).

The reduction of paper thickness in printed books by, let's say one third in about 75 years, has at least four important results. All four effects are economic. First of all, more sheets of paper could be produced with the same amount of raw materials. Compared to 1473, about one third more in 1550. Second, if the weight of books is lowered, transportation costs decrease as well. Third, printers, publishers and booksellers need less space to warehouse copies waiting for sale. Fourth, purchasers need less space to shelve books.

In spite of the economic benefits of the reduction of the paper thickness, this process had reached its limits around the middle of the sixteenth century. Very thin paper has also disadvantages. First of all, it is much harder to manipulate and to print on it with a relief press without piercing it. Second, thinner paper is more translucent and may show the printing on the verso, which disturbs reading (Figure 8). In addition, it is probably more difficult to manifacture.

Fig. 8. **Text of the verso showing. Fernando del Castillo, *Concionero genera*l. Anvers: Martin Nucio, 1557, octavo (copy Royal Library Brussels, LP 5.523 A, fols. A1v-A2r. Ten leaves have a thickness of about 0.732 mm)**


COMIENÇA LA TABLA
DESTE CANCIONERO.
Primeramente las obras de Moſſen Iuan Tallante por ſu orden. Folio.1
Otra copla del Bizconde de Altamira que hizo à las cinco letras del nõbre de nueſtra ſeñora. 14
El aue Maria trobada por Hernan Perez de Guzman. 14
El pater noſter hecho por el miſmo. 14
Gloſa del Bachiller Alonſo de Proaza à vna cancion en loor de ſanta Catherina de Sena. 15
Tres coplas ſuyas en loor de la dicha ſanta Catherina de Sena. 16
Otras coplas del cõde de Oliua ſobre el ecce homo que dixo Pilato à los Iudios. 17
Otra obra de Nicolas Nuñez en loor de ſant Eloy. 17
Cancion de Iuan Rodriguez del Padron con la gloſa de Tapia en loor de nueſtra ſeñora. 18
Vna copla ſola que dize aſsi: O buen Ieſu redemptor. 19
A 2

9. Conclusion

The changes in paper thickness during the first decades of printing had lasting effects both on book design and economy. The reduction of paper thickness allowed for savings on many levels, and probably helped meeting a dramatically increasing demand. The success of this process lays in the fact that it went by slow enough to remain basically unnoticed – not in the last place by most scholars.

In spite of its relevance for our understanding of the development of the book market, the research of paper thickness in the handpress era is scarcely out of the egg. The desiderata in this field are legion. On a methodological level, we still need better to understand the impact on paper thickness of binding and rebinding. Neither do we know how differences in storage climate (temperature, relative humidity) work out on paper thickness. Also the compression effect of paper requires more study. To what extent, for instance, does it depend on paper thickness and on different levels of sizing?

More data are required in order to identify correlations other than time. It is likely that the other two dimensions of the sheet (height and width) can be linked with thickness. There are strong indications that printers opted for thinner papers stocks for smaller bibliographical formats. We also have the impression that they opted even more consciously for paper with specific characteristics in the case of specific projects, especially in the second half of the sixteenth century and later. It is a fact that printers and publishers such as Christophe Plantin (c. 1520-1589) and his successors systematically exploited the possibilities of paper for product differentiation.

To conclude, it is obvious that this subject requires an international approach.

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Andrea Ottone

Market assessment and risk prediction: resources and know-how of a seventeenth-century bookseller of Venice coping with competition

1. Growing competition and growing information

If observed from the perspective of current survivals, the 1580s can be seen as the golden age of book sale catalogues.[1] The question is opened whether a greater number of survivals of book sales catalogues from the 1580s onward may be caused by an increasing production (of both single editions or an augmentation of their average pressrun) or an enhanced practice of preservation. Regardless the reason, evidence converge in the same direction: towards the end of the sixteenth century, book sale catalogues were progressively acquiring a greater relevance for both consumers and producers. The obvious ramification of this phenomenon is that among the actors of the Renaissance book trade there was an increasing awareness regarding how their economic space was both expanding and getting progressively crowded and their operations were getting overall more complicated. In other words, bookdealers were getting growingly preoccupied with an exacerbating competition. Book catalogues were clearly a form of advertisement that responded to the necessity of positioning one's commercial offering in a growingly difficult environment. The practice of self-advertisement shows a growing concern that single

[1] I owe this notion to Christian Coppens who so generously shared it with me while working on a comprehensive survey of book sales catalogues printed in Europe. To his future publication on this matter, I shall address the reader. His previous publications on the subject comprise (Coppens 2008; Coppens and Nuovo 2018). Another source of information on the greater density of bibliographic information on book sales catalogues post 1580s is the EMoBookTrade project, which sees me as a proud member. Said project between 2016-2022, has devoted its attention to gathering information on book prices at the beginning of the print age. Most of the sources of data acquisition are printed catalogues. A look at the back-end perspective of the catalogue will confirm how current remaining of sales catalogues carry a date later than 1580 or may be attributed to that period when a date is not declared in the source. A survey of the sources so far entered in the EMoBookPrices database can be completed here: https://emobooktrade.unimi.it/db/public/pages/sourcespriceslist. Along the way I often used the generous help of several persons that I would like to thank: Carolin Strecker had often had to listen to my thoughts on this Collection 170/622 and read my first draft. My frequent conversations with Francesco Ammannati, Flavia Bruni, Christian Coppens, Angela Nuovo, Renaud Milazzo and Joran Proot have been fundamental to adjust my argument. I would also share my gratitude with Serena Malavasi and Lucia Botindari. Part of my studies on this topic have been conducted with the support of the Ahmanson Research Fellowships that was granted to me in 2018. My gratitude goes to the CMR Center for Early Global Studies and to the personnel of the Department of Special Collection at UCLA's Charles E. Young Research Library. My gratitude goes to Megan Drinkwater for revising my paper and for sharing her advice.

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Referee List (DOI 10.36253/fup_referee_list)
FUP Best Practice in Scholarly Publishing (DOI 10.36253/fup_best_practice)

Andrea Ottone, *Market assessment and risk prediction: resources and know-how of a seventeenth-century bookseller of Venice coping with competition*, © Author(s), CC BY 4.0, DOI 10.36253/979-12-215-0092-9.18, in Giampiero Nigro (edited by), *L'economia della conoscenza: innovazione, produttività e crescita economica nei secoli XIII-XVIII / The knowledge economy: innovation, productivity and economic growth,13th to 18th century*, pp. 315-330, 2023, published by Firenze University Press, ISBN 979-12-215-0092-9, DOI 10.36253/979-12-215-0092-9

publisher had that their portfolio may be overlooked due to the availability of a rising number of different concurring offer of similar products.

The way in which individual publishers coped with the difficulties of an overcrowding market may be observed by pinning down a few metatextual elements found in book sale catalogues. A brief excursus over a selection of them may reveal the tricks used by publishers to lure and consolidate their constituency within a selected marketspace. A relatively limited publishing initiatives like that of the Giolito family, active in Venice and chiefly projected to an Italian speaking audience, would circulate a small format catalogue with listings organized alphabetically. They would use vernacular Italian addressing their advertisement mainly, but not solely, to a peninsular audience interested in a portfolio which, in fact, mainly comprised vernacular literature. They would provide prices in Venetian lira, knowing that their listings would rise the attention mainly in those regions of the Italian peninsula dominated by the Venetian book market.[2] A way larger operation like that of the Plantin-Moretus family would boast a selected number of publications on a 1579 broadsheet with an elaborated set of designs framing a polyglot text, hence addressing a wide erudite audience potentially scattered all over Europe and beyond. They would organize their listings by genre and, within each section, listings would be distributed in alphabetical order. The commercial taxonomy deployed by the Officina Plantiniana would comprise standard categories such as low books, history, and geography, Greek and Hebrew (hence addressing a highly erudite audience). However, the linguistic component would be dominant in said commercial taxonomy and it would brag publications in vernacular Flemish, quite sensical for a publishing house based in Antwerp, French, Spanish and Italian, hence asserting the diverse potential of their output, the capability, and ambitions of their distribution network. Prices would be absent, probably to adjust their sales to the contingencies demanded by the choice of directing such a wide operation in different geographic and commercial contexts, hence enabling them to flex their sales opportunities to many other unpredictable exigencies that a fixed price, expressed in any given currency, would not as easily allow. The fancy outlook of this spreadsheet catalogue, suited to be posted in display at fires or other selling posts, for passersby to admire was completed by an elaborated trademark placed at the bottom right to attract the attention of customers to a very articulated and laudatory address to the reader composed in fine Latin.[3] A similarly large operation was that of the Giunti publishing house of Venice. Reliant on a wide distributing network, the Giunti would advertise listing on a spreadsheet manifesto, with friezes framing a text almost exclusively in Latin. Prices would be provided in Venetian Ducati, a heavy metal currency with which many in the know merchants, either sub or trans-alpine, must have been acquainted with if they did business in a relevant trading post like Venice. Their 1591 and 1595 catalogues proposed an advertisement format displaying listings grouped by literary genre organized according to an academic hierarchy of knowledge spanning from the quadrivium to the higher education, hence luring an

[2] See for example Perugia, Biblioteca Augusta (henceforth BA), Ald 558(13 and ibid., Ald 558(14. Both catalogues are available in open access in (Panzanelli Fratoni 2018, 104-105).

[3] BA, Ald 558(11. See (Panzanelli Fratoni 2018, 102).

audience aiming or belonging to the high professions: legists, physicians and clergy.[4] Lastly, a more modest dealer would be Giovanni Domenico Tarino, who's commercial orientation were mainly influenced by the legacy of the Bevilacqua family with whom he collaborated and by whom he installed his activity in the early seventeenth century. His undated post 1609 catalogue would carry many listings in Latin and addressed mainly to an erudite audience interested in law books (both civil and canon law), casuistry or other religious works. His limited network must have constrained him to a subalpine mostly Latinate audience; hence the heading was in vernacular Italian, although his listings were mainly Latin, and his prices were in the local Piedmontese currency (Florin) with some indications on currency exchange still mainly meaningful to a peninsular merchant.[5]

By using elements such as taxonomy, visual aids, pricing and language, publishers were clearly aiming to consolidate and expand their audience. In doing so, they were carving their own special place in the market by addressing specific areas, both geographic and social.

This limited excursus on the outlook of late Cinquecento and early Seicento book sale catalogues were aimed to uphold one point. With competition growing in the book trade, and with spaces of maneuver shrinking while the European market was saturating, publishers were forced to resort to creative methods to cope with the heating friction between similar, if not identical commodities circulating a growingly tight market. Resorting to advertisement strategies was progressively becoming a must. Much of the same phenomenon could be observed in the transformation of titlepages into public arenas where publishers would showcase the alleged or factual novelties that distinguished their editions from previously circulating ones. This paper will argue that advertisement via an outbound flux of bibliographic information from printing centers onto the periphery of European readership would not suffice, especially not when knowledge of how dense the community of European publishers would have become by the second half of the sixteenth century. It will further argue that more refined computational skills of inbound bibliographic information were called for if a publisher or bookdealer was willing to tame a wild horse such as the late Cinquecento book market had become. With both the publishing and the retail practice becoming a risky business an efficient storing and managing of updated information regarding the state of the market of reference was necessary. The limited vision that early modern merchants had over the complex folding of their own transnational market was certainly a limit. Despite the poor communication that premodern Europe offered, early modern book dealers had all that they needed to do endeavor into a rudimentary systematization of relevant information they sought to operate a sound business planning. Record-keeping diligence and a computational mindset (fostered by the numerous

[4] BA, Ald 558(8. See (Panzanelli Fratoni 2018, 99). A closing section of the catalogue would advertise a small group of vernacular Italian works, clearly placed at the periphery of this catalogue, as much as peripherical was the publisher's interest for a non-Latinate audience.

[5] «Lista de libri di Gio. Dominico Tarino, stampati in Torino, con il prezzo loro: auertendo che grossi 12 fanno vn Fiorino e Fiorini 10, Grossi 6 fanno vn Scudo d'oro d'Italia.» See (*Lista* [1609]); a known copy can be found at Perugia, Bibl. Augusta, Ald 558(10. See also digital reproduction in (Panzanelli Fratoni 2018, 101).

abacus schools) were mandatory skills for late Renaissance merchants. Most importantly, however, publishers and bookdealers at large, could count on an ever-growing influx of bibliographic information which were spreading over Europe via sales catalogues.[6] Furthermore, *ad hoc* catalogues could be fairly easily compiled by publisher by simply retrieving bibliographic data from the very edition that were circulating via commercial and private channels around the continent and beyond. Title pages and colophons, in fact, stored most of the information necessary for cataloguing relevant commercial details. The manuscript volume that this article centers upon is one such example of how book dealers of the Renaissance made use of the many bibliographic information circulating at the time to build their own catalogues to refine their knowledge of their own commercial area of interest.

2. Bernardo Giunti and his alleged Stockbook

This section will focus on a single manuscript which, it will be contended, shed light on the ability that early publishers had to assess their market of interest to measure the redundancy of circulating edition and, hence, plan their commercial strategies accordingly. The manuscript in question is Collection 170/622, preserved at the Charles E. Young Research Library, Department of Special Collections, at the University of California, Los Angeles. The manuscript is commonly known to scholars as the «Giunta's publishing house stockbook» and so is it currently catalogued at the holding institution. To my knowledge the first to have used the term stockbook in reference to this manuscript has been Martin Lowry (Lowry 1991). His work has been pioneering in two ways: not only did his work revived scholars' attention on the issue of book prices but it also brought to the spotlight an extraordinary repository of information on Renaissance publishing such as ms. Collection 170/622. His undoubted scholarship however could not rely on the bibliographical resources and digital tools that were made available to scholars some ten years after his study was published. The digital revolution progressively encouraged book historians thinking in terms of big data. That was for example the effort of the EMoBookTrade project which analyzed an array of sale book catalogues comparatively. Only a linear exploration of the dataset contained in manuscript Collection

[6] Catalogues proved to be commodities suitable for multi-purposes exchanges. An interesting case of commodification of commercial catalogues emerges from the archive of the Congregation of the Index. The Roman institution showed its interest by having a hold of recent copies of the Frankfurt Fair's catalogue for policing purposes. Clearly watching over the offering of Italian and transalpine publishers meeting in a protestant city was of much interest for a censorial office in order to have a feel of the status of the production and circulation of contested material. Venetian book dealers returning from the fair were solicited to send over a copy of the recent Frankfurt Fair's catalogue over to the central office of the Congregation for the Index. Venetian publishers, on their part were almost always in need of special dispensations and corrective material produced by the Roman Congregation in order to operate their presses and plan their publishing. The Roman congregation proved to use such constant need of the Venetian publishers to extort them a copy of the latest catalogue. An example of this trading of bibliographic intelligence in exchange of institutional favors emerges from the following correspondence occurred between July and November 1601 between Rome and Venice: Vatican City, Archivio della Congregazione per la Dottrina della Fede, Index, V.1, ff. 140v, 144v, 163v and ibid., III.6, f. 298r. Further details on this matter can be found in (Ottone 2022, 272, fn. 30).

170/622 and a comparison between the inner logics of this and other commercial sources of the time could reveal that wat was previously consider a catalogue of books in stock was in fact an even more fascinating tool of commercial planning. My present work builds on Lowry's scholarship and tries to propose a different definition of Bernardo Giunti's own's manuscript. One must in fact take into account that Lowry's main goal was not to investigate the nature of the manuscript he was surveying but, rather, to derive valuable information on the Manuzios' pricing policies.

Before diving into the ambiguities of Bernardo's own manuscript, some attention will be given to its very owner and, likely, main compilator. Bernardo Giunti was a rather marginal member of the Giunti family, a transnational network of publishers originally from Florence, with a well-established presence in other Italian states as well as in Spain and France. The barycenter of the Giunti's commercial network was Venice, where the family's enterprise likely took momentum.[7] Bernardo di Bernardo Giunti was born in Florence around 1550. When still a minor, his father Bernardo senior, leader of the Florentine branch of the publishing house died, leaving behind a suffering business which was unable to foster the professional ambitions of his five mail heirs. Filippo and Jacopo then already adults, seized the firm leaving their three brother no other option than seek their fortune elsewhere. Giulio and Luca went to Madrid to further consolidate the Giunti's presence in Spain and Bernardo went to Venice to try his luck under the watchful guidance of Lucantonio senior, leader of the Venetian branch and indisputably the most prominent member of the transnational firm.[8] There, Bernardo's publishing activity did not seem to prosper, or at least not in comparison to what other Giunti were achieving in Venice and beyond. His greatest achievements in terms of publishing came mainly when he was in partnership with someone, initially his two brothers Filippo and Jacopo and, at the turn of the century with a book business connoisseur like Giovanni Battista Ciotti, Senese in origin but very well established in Venice and equally well connected with the Frankfurt commercial scene.[9] His partnership with Ciotti began exactly in the year 1600, which is also the year when Bernardo Giunti started assembling his manuscript catalogue.[10]

Ms. Collection 170/622 is a bibliographic directory comprising some 11.000 entries. A greater number of enlisted editions date from the late 1570s to the 1640s.

[7] On the origins and comprehensive history of the Giunti's enterprise a lot of work has been made by Alberto Camerini (1962-1963), William Pettas (1980; 2013) and Alessandro Barbero (2022).

[8] A precious account on Lucantonio Giunti's personality and business posture and commercial success can be found in (Tenenti 1957).

[9] Giovanni Battista Ciotti publishing endeavors and business approach are well described in (Maclean 2013) and (Rhodes 2013).

[10] The manuscript has a ownership statement and a beginning date right at the ideal front page YRL, Collection f. 4r. The indicated starting date is March 1st, 1600. This date, I believe, must be taken as ideal, as ideal since the it indicates the beginning of the Venetian calendar. However, a linear survey of the entries reveals how the earliest data were entered between 1600 and 1604. Details on the methodology used to consolidate these assumptions are provided in (Ottone forthcoming).

The latest edition that I could find so far is dated 1643.[11] Hence, the active life of the manuscript must have been 1600 (the declared year when the manuscript was initially compiled) to the 1640s. Entries, at their best descriptive level carry information on title/author, format, publisher, number of printing sheet and price (e.g. «Epistolae di Tullij. In 8°, Griffo, C. 33, L. 1.4»).[12] Very rarely, information on the year of publication is provided (e.g. «Epistolae familiares. Altobello, 1586, C. 33 ½»).[13] The steadiest element in the descriptive standard of the manuscript is the sheet count (i.e. the number of printing sheet employed to assemble the enlisted edition). This for publishers was the chief quali-quantitative element when it came to thinking about the bare facts of their business. The sheet count provided the synthetic representation of the merging of expenses related to raw material and labor: press people, composers and proofreaders were all paid per printing sheet produced (or in the case of proofreaders, per printing sheet corrected and collated). When information on the number of printing sheets was associated to information on book price (and in Bernardo's catalogue often, but not always, is), an agile and well-trained mind could spot the cost-price/effort-gain ratio. Entries could however be way more imprecise and just list a title or little more: «Esopi. Combi, C. 13» or «Esopi. In 16°, Serena».[14] These barebone entries are not so frequent in Bernardo Giunti's catalogue, but ironically, they are the most useful to define the inner logic of the catalogue, as they circumscribe the minimum requirement an entry should display in order to fit the purpose of Bernardo's listings. Entries with such little descriptive elements serve a purpose alone: they maintain that a given edition existed in a given time of interest for the compiler. This is exactly what Bernardo's catalogue did best: assert the presence of commodities of interest in a specific time and space.

Bernardo Giunti's catalogue has been referenced to as a list of books in stocks likely because of the fact that knowingly, Bernardo's main activity was that of publisher and book retailer. Hence it made sense to hold the idea that an extensive list of editions would reflect the book holdings of his shop or that of the Giunti of Venice. A commonsense idea that, unfortunately collide with several internal evidence.[15] The most perplexing element is the fact that Bernardo Giunti blatantly in-

[11] «Avvento sacro di Serafino di Sera. Folio, Leggi, 4°, C. 108 ½ […]» (University of California, Los Angeles, Charles E. Young Research Library, Department of Special Collections (henceforth YRL) Collection 170/622, f. 138v, item 40). The entry matches (Leggi 1643). See also (Catalogo del Servizio Bibliotecario Nazionale (https://opac.sbn.it/), UM1E\001310).

[12] YRL, Collection 170/622, 11ra, 19.

[13] Ibid., item 30.

[14] YRL, Collection 170/622, f. 12v, respectively items 18 and 16. «Combi» refers to Venetian publisher Sebastiano Combi (EDIT16 (https://alphabetica.it/web/edit-16), CNCT 256); «Serena» or *Sirena*, was the insigna of the Varisco family; the entry matches (Aesopus 1595), hence it also matches the tenure of the Varisco publishing was that of Giorgio and Marco. For a sample of the edition see (EDIT16, CNCE 409).

[15] A systematic survey of the reasons why I contend that ms. Collection 170/622 escapes the purpose of this paper. A linear assessment of the evidence can be found in (Ottone forthcoming).

corporates somebody else's' printed catalogues to build his own dataset.[16] This notion alone conflicts with the commonsense idea of an inventory of books in stock. Furthermore, a common element of inventories is that they carry information on the quantity of commodities that are being inventoried. Quantities are in fact the key element in an inventory whose purpose is to crystallize the value of a standing patrimony. Bernardo Giunti's catalogue carry no information on quantity per item.[17] One may argue that quantities were expected to be a dynamic element if the alleged stockbook was meant to be a search aid to browse the standing presence of a stock of books in sale in a Venetian bookshop. However, inbound and outbound movement should have been recorded to make the stockbook a useful directory for the shopkeeper to navigate the stacks. Instead, the catalogue solely records the sedimentation of bibliographic data for a timespan of over forty years. An inventory of this kind would have either mislead the shopkeeper in search of long sold books or, inversely, it would have been the testimony of a glorious business failure: that of a bookshop that stubbornly accumulated commodities that would not sell for over forty years. An alternative hypothesis could be that the manuscript was mainly a directory of prices. However, if prices are indeed well represented in the listings, they are however not constantly present. Their exact incidence among the listings cannot still be assessed but an approximate estimation would be that some fifty percent of the entries indicate a price (or, at times, even more than one). No wonder that indication on prices was so unstable in a tool that lived an active life of over forty years. It is hardly the case, that prices would in fact stay stable for this long. Summing up, the presence of data derived from secondary sources (i.e. printed sale catalogues) and the long span of the active life of this manuscript are the greatest evidence against the stockbook being in fact a catalogue of books in stock. Instead, a suitable hypothesis is that the catalogue was a directory aimed to aid the user to browse a virtual repository. But which virtual repository then?

The greatest clue that helps cracking the code of this ambiguous manuscript lies on the almost complete disentanglement of the editions that Bernardo Giunti chose to enlist in his manuscript catalogue, with the potentialities of the commercial network that the Giunti so carefully established over the years, mostly thanks to the entrepreneurial vision of Lucantonio Giunti senior, founder of the Venetian branch of the firm. Throughout two centuries the Giunti carefully placed family members in Spain (Burgos, Salamanca and Madrid), France (with a strategic presence of a family member in Lyon, the city where a relevant national fair would meet. In Italy,

[16] So far, I spotted at least three occurrences of said copying practice: Giovanni Tarino's (Lista [1609]) is copied almost linearly at YRL, Collection 170/622, ff. 267r-268r. Listing derived from the (*Index* 1595) can be found scattered across entries at YRL, Collection 170/622, ff. 5r-165v. Niccolò Misserini's 1600 printed catalogue (*Libri* 1600), can be found mainly scattered in YRL, Collection 170/622, ff. 123r-136v (I am grateful to Giliola Barbero for drawing my attention to the incorporation of Misserini's data in Bernardo Giunti's manuscript).

[17] An example of how a bookshop's inventory would be conceived in the Cinquecento comes exactly from within the Giunti's network, albeit from Spain can be found in (Pettas 1995). The document in question does carry exact information on quantities per item enlisted. This was a necessary information to resolve or prevent legal controversies that, most often the reason behind the drafting of an inventory, such as is for example the case of Juan de Giunta's catalogue here referenced.

Venice and Florence were their main hubs but, throughout the sixteenth century the Giunti was able to establish their presence in several other key or minor centers of the booktrade. While Bernardo Giunti was active, the Venetian branch of the family, with which he was clearly collaborating,[18] could count on a vascular network of subcontracted collaborators operating in several Italian cities.[19] Very little of this network of direct franchising or agents is represented by the geographic spectrum of Bernardio's bibliographic catalogue. This factor poses another heavy burden on the hypothesis that Collection 170/622 could have been an inventory of book acquisitions. It would in fact be strange that in compiling their stock the Giunti of Venice (or Bernardo alone) would disregard the commercial potentials of their standing network. The mismatch between the geography of Bernardo's catalogue and the geography of the Giunti's network, as anticipated also provide a clue to unpack the enigma of the nature and function of the manuscript bibliographic directory that Bernardo and others so carefully compiled for over forty years. It was no doubt a search directory, as its multiple search aids reveal. But what were the queries that brought users to consult this massive repository of bibliographic information?

With an eye to the internal geography of ms. Collection 170/622 (i.e. the provenience of the editions therein enlisted) it becomes clear how the greatest potential of the manuscript was to inform users on the state of the art in term of publishing output of the book market of north Italy, particularly the north-east. This was clearly the slice of the book market that was of greater interest of a small to medium scale bookdealer like Bernardo Giunti. Not only a great number of listings overall contained in the catalogue are coming from said region, but also, and this is even more telling, the compilers went a long way to endow the catalogue with specific search aids that would help users to navigate the data by provenience and did their best job in providing stronger search aid in the area of the manuscript that enlisted Italian imprints. These search aids consisted of tags surfacing outside the righthand margin of the volume and, most importantly, a pagination system (from 1 to 39) that was exceptionally used in the portion of the manuscript that focused on the Italian imprints (ff. 248r-267v).[20] Search aids can be also found in other portions of the manuscript but not with the same narrowness shown in the mentioned section of the catalogue. Much of the same data found in this portion are also repeated in the second most prominent section of the catalogue (ff. 5r-236v) which organizes largely the same listings by subject-matter.[21] The by-subject portion of the dataset,

[18] Minutes from the meetings of the Venetian guild of printers reveal that Bernardo Giunti acted within the guild jointly with Lucantonio Giunti (Camerini 1962-1963, II, 452-53) and later with his two sons to defend their direct commercial interests with reference to the commercialization of liturgical literature (Camerini 1962-1963, II, 454-55).

[19] This network has been impressively reconstructed in (Tenenti 1957).

[20] Overall, the by-provenience portion of the manuscript occupies ff. 137r-268v of Collection 170/622 which covers also a number of transalpine editions which will be discussed later. A number of digital reproductions of the manuscript Collection 170/622 can be found in the open access publication (Ammannati and Nuovo 2017). The whole manuscript is currently accessible online via the YRL digital catalogue.

[21] Ibid., ff. 5r-236v

much like the Giunti 1591/5 printed catalogue discussed before was organized by scholarly categories that mimicked the study curriculum of students involved in the higher education (humanities, philosophy, theology, canon and civil low, medicine, liturgy).[22] Within each of these thematic categories, letter-tags would ease alphabetic searches by author or title. Within each letter section listings were grouped by typographical format. The by-provenience portion of the manuscript gathers listings by macro-regions, i.e. Germany and Italy. Significantly, information on the provenience of said editions was sporadic but not absent, again, with special regard to Italian imprints. In sum, several internal evidence would suggest that browsing listings by provenience was in all ways enhanced in Bernardo Giunti's catalogue, and Italian imprints occupied a special place in his investigative practices.

So much interest in surveying the dataset of Italian proveniences, hence a market space largely dominated by the Venetian book industry, was probably aimed to guide Bernardo, and his acolytes, in draft business planning, publishing policies and retailer strategies. Rather than a directory of books in a physical stock, Bernardo's catalogue seemed to be quite the opposite. By selectively noting down the recent imprints of his most proximate competitors or allies, Bernardo Giunti was compiling a list of books that one should have been get a commercial distance from, both as a publisher and a retailer, as they were already circulating in his market of interest, hence saturating further commercial opportunities.

This hypothesis, however, shows one weak spot that needs further discussion. If Bernardo Giunti's catalogue was so invested in getting a pulse of the market most proximate to Venice, then why so much interest also in recording a good deal of German imprints? The «Catalogue of books printed in Germany» in fact occupies 43 densely written ad alphabetically organized leaves (with side letter tags) of his catalogue. So much interest on the German market would be particularly unexpected, provided that the Giunti had no direct link to that commercial area.[23]

Germany however was closer to Venice than one would normally expect, hence, much closer to Bernardo's interests than his family's commercial network would show. For starters, his friend and associate Giovanni Battista Ciotti was a habitual visitor of the Frankfurt book fair. Quite intriguingly, the partnership with Cotti begins exactly when Bernardo's manuscript volume begins, in the year 1600. It is more than likely that his new associate would share commercial information with Bernardo in the form of sale catalogues that would normally converge at the international fair as an advertisement tool. It is also true, however, that Bernardo Giunti did not necessarily need to have an indirect chain of transmission with the German book market. German merchants were normally flooding the city of Venice to transact a diverse number of commodities, including books. All Bernardo had

[22] Ibid., ff 137r-165v occupies a gray zone as it gathers information on editions in vernacular Italian printed in Venice. As the Giunti 1591/5 catalogues (*Index* 1591; *Index* 1595) other minor categories would appear: Greek and Hebrew books, for highly specialized scholars, and vernacular literature, the closest genres to escapist literature for non-specialized customers.

[23] YRL, Collection 170/622, ff. 206r-248r: «Catalogue of books printed in Germany» («Catalogo delli libri stampati in Germania»). What very likely this section ended up being in fact was a selection of information of books displayed at the Frankfurt fair. This is so far only a working hypothesis based on the notion that some of the listings included books printed in Antwerp, Lyon, and Paris.

had to do was to walk to Rialto, where most of the transnational business took place in Venice, as well as most of the book retail. Quite significantly, next to Rialto bridge, on the San Marco side of the canal, Germans had their own warehouse known as the Fondaco de' Tedeschi. In short, the German portion of ms. Collection 170/622, albeit counterintuitively, was part of the general survey that Bernardo was conducting on the Venetian local market. An up-to-date knowledge of the general status of the German book market would have allowed Bernardo to better assess what to receive and, most importantly offer to German retailer visiting Venice.

3. David versus Goliath: Bernardo Giunti versus Christof Plantin

Collection 170/622 may be one of the few artefacts revealing how book dealers approached market strategies with more than just a good instinct for their trade. The idea that complex, costly and risky operations such as publishing and retailing book required a good deal of planning, had long circulated among book historians. But the question of how they could deal with the intricacies of a wide and fast evolving transnational market such as that of the Renaissance while coping with the limits of premodern communication has often been left open. Looking at Bernardo Giunti's bibliographic directory it seems that their method was in fact simple and manageable for an early modern merchant, although the conceptual implications of a tool like the one devised by Bernardo are to some extent impressive and need stress.

To these days only another catalogue that shows partial similarities to Collection 170/622 has surfaced, and that is Christoph Plantin's M. 296.[24] The two directories display some qualitative common features. These are for example the outlook of the single entries (mentioning either author or title, or both, format, sheet count and price), the grouping of multiple listings according to commercial categories (mainly, provenience and publisher), and the alphabetical organization of data within classes. However, some differences need to be pinpointed. Plantin's catalogue M. 296 does not display the dual organization of data by subject and by provenience and is rather focused on proveniences, grouping entries by macro region, i.e. language areas, print centers and publishers (Milazzo 2020, 184; 2021, 146). Furthermore, lateral search tags are not present in the manuscript and users were relying mainly on their capacity to browse information alphabetically in a volume of 425 leaves. The considerably larger size of the manuscript is one of the justifications for the Goliath versus David analogy proposed in the heading of this section. In quantitative terms, not only does the Plantin-Moretus volume outnumbers Bernardo Giunti's catalogue by 112 leaves, but also the number of entries available is overwhelmingly greater: ca. 20.000 entries in the Plantin-Moretus manuscript versus the ca. 11.000 found in Bernardo Giunti's one. The quantitative distance becomes even greater if one considers that the data in Bernardo Giunti's catalogue tends to repeat between the two main sections of the volume: the one that organizes data by subject and the one that organizes data by provenience.

[24] Antwerp, Plantin-Moretus Museum, M 296. The purposes and potential of this manuscript is discussed in Milazzo 2020.

The quantitative differences found in the two catalogues under scrutiny is justified by the different magnitude that characterized the operation directed by the Plantin-Moretus publishing house and that operated by Bernardo Giunti alone or in partnership with Giovanni Battista Ciotti. The Plantin-Moretus publishing house aimed virtually at a global market comprising Europe and, via its relationship with the Spanish crown, the emerging colonies. Moreover, the Flemish firm was greatly invested in publishing and commercializing its own publications, aside from reselling other publishers' initiatives. In the case of Bernardo Giunti, with his known signed editions being so modest in number, it may have been the case that his activity as a retailer had priority over that of publisher. With Planten-Moretus' goal being that of dominating a market that went throughout and beyond the continent, the array of information that the firm needed to master was by far greater than the ones necessary to Bernardo who mainly operated a sub-transalpine firm. Hence, the quantitative difference finds its clear explanation. Furthermore, the size of the firm and the number of collaborators that could work on gathering and implementing data in the two catalogues must have also made a difference.

But the smaller size of the dataset put together by Bernardo Giunti has ironically some advantages for current historians interested in dissecting the practical knowhow of bookdealers. A limited dataset like that of Bernardo Giunti speaks more clearly than the overly eloquent M. 296 in use by the Plantin-Moretus firm. For instance, it defines more clearly the scope of the planning strategies of a medium to small regional book dealer operating in a printing center that, although used to dominate the market, was now feeling the bite of northern centers, especially Antwerp, where the Plantin-Moretus firm operated. Therefore, Collection 170/622 defines quite clearly the minimum requirement in terms of business planning necessary to a book dealer who wanted to just stay afloat in a growingly competitive market.

Whereas M. 296 does a great job of compiling refined data for a very large continental market, Collection 170/622 compiles as many data available for the most relevant local market that a dealer operating mainly in Venice could aspire to work with: most of relevant northern Italian cities, some relevant central and southern Italian cities and Germany (due to its strategic relevance for the retail activities of Venice). In the composition of data, Bernardo Giunti did his best to acquire as many information as possible, but eventually he could lose some on the way. The first victim of this information decay were prices. Very interestingly, the earliest stratification of data most of the time carried information on prices whereas that was not much the case for later entries.[25] Hence, prices were a relevant information at the earliest stage of the data entry endeavor, but compilators partially lose interest on this element as time passed. Number of printing sheets was a steadier element. This could valuably replace information on price as barter was part of the way bookdealers carried out their transactions (Maclean 2021, 50-51). But this in-

[25] This is particularly clear in the section of his manuscript that classifies edition by subject-matter (YRL, Collection 170/622, ff. 25r-136v). The morphology of the text on each leaf along the matching of single entries with surviving editions allow a tentative analysis of the data. Metatextual elements such as the distribution of text within the space or changes in handwrite are also taken into account in this analysis.

formation, at times, could also be skipped by the compilators of Bernardo Giunti's catalogue. The information that they were most interested in keeping track of was by all means the presence of a given edition within the market of direct influence of the Venetian publishing industry and, eventually their later recurrencies (i.e. later editions of the same title). Published works were, however made sense in terms of commodities. This means that compatible commodities had to share not only their content, but also their outlook, most importantly their typographic format. Ultimately if the Planten-Moretus catalogue did a great job recording prices differences per analogous commodities (no wonder M. 296 also does a better job of noting down the year of publication of the enlisted editions than Collection 170/622 does), Bernardo Giunti's artefact was mainly good at keeping track of the redundancy of the same commodity in the commercial space that was of interest for Bernardo Giunti's enterprise. This seemed to be the vital information that a mid to small size book entrepreneurs needed to acquire when looking at expanding their operation, like Bernardo Giunti did when entering in partnership with Giovani Battista Ciotti.

This last conclusion calls for a discussion of another relevant difference between the Christof Plantin catalogue and the Bernardo Giunti catalogue, that is their span of active life. Renaud Milazzo convincingly contend that data were entered in M. 296 between 1572 and 1596. Its active life lasted for twenty-five years or, likely little more. Collection 170/622, instead, was implemented between 1600 to, at least 1643, hence, for almost twice longer. Two hypotheses are possible: one is that within twenty years the width of Plantin-Moretus' operations expanded so much that that the data contained in M. 296 became obsolete. The second could be that after over twenty years the greatest asset of M. 296 (comparing prices in a continental radius) would become completely unreliable.

A much safer hypothesis can be made for Collection 170/622. The catalogue, less invested in controlling the market value of the commodities under watch could instead preserve a longer standing potential in surveying the saturation of the local market by the enlisted editions. So capable was this potential of the catalogue that Bernardo Giunti's catalogue outlived its original creator to be used by others after him.[26] Fourth years after its assembling, the best operational feature of the catalogue, i.e. controlling the saturation of the local book market must have greatly weakened and its implementation ceased. By the 1540s the local book market must have looked much different in terms of the local demand and the global offer that was flooding it. Forty years in early modern terms would comprise at least three generations of collectors. By that time new authors and even new literary trends had emerged and the Bernardo's compilation of bibliographic information must have become obsolete to assess the trends of not only firsthand but even secondhand acquisitions.

[26] Bernardo di Bernardo Giunti fades away from sources little earlier than the 1630s (Camerini 1962-1963, II, 527) when he must have been already in his eighty.

4. Common knowledge or publishers' book of secrets

The question of how Bernardo Giunti may have acquired the rudimentary knowhow to pursue computational analysis of market trends needs some reflection. Unfortunately, it is still difficult to offer a definitive answer. Clues suggest two distinct tentative hypotheses, both equally possible. One hypothesis would be that Bernardo Giunti learned the practice of rudimentary market surveyes within the circles of his own family. This is based primarily on the contiguity that his work had with the enterprise of Lucantonio Giunti. An enterprise of the size like his could hardly prosper in the transnational market without developing an efficient way of controlling the viability and profitability of his publishing endeavors. That implied a thorough knowledge of what the market was capable and willing to absorb. One problem with this argument may be that the available information does not allow to assert that Bernardino started his market research practice earlier than the year 1600, whereas his career as a bookman started in the 1570s. The hypothesis that he may have had a previous such catalogue as Collection 170/622 is inviting, however, to these days, still unsupported by evidence. Morover, the fact that the year 1600 sees both the start the Giunti-Ciotti partnership and the start of Bernardo Giunti's data collection may hardly be a coincidence. When Bernardo's activity as a publisher took a leap forward thanks to the partnership with Ciotti, then his new position required him to move a step ahead in his commercial strategic planning. Hence, factual evidence and clues would concur to suggest that the 1600 catalogue was Bernardo's first endeavor in a systematic practice of assessing his market of interest.

Almost certainly Bernardo Giunti's method of assessing redundancies of editions in his market of interest was hardly his own invention. His manuscript bibliographic repository is too similar, albeit not identical to that used by the Plantin-Moretus publishing house. Did Bernardo Giunti learn of this practice via his transalpine connections? This would be the second hypothesis suggested by some of the available clues.[27] In all fairness, Bernardo Giunti's bibliographic directory begins just four years after the latest entry is entered in the Plantin-Moretus catalogue. This is also an irresistible coincidence. If one would like to argue in favor of a filiation between the former and the latter catalogues, a possible vehicle of this commercial method of market bibliometric may have been Giovani Battista Ciotti. He, like Christoph Plantin, was a frequent attendant of the Frankfurt fair. There Ciotti may have learned the valuable secret of northern merchants who just started asserting their leadership in the European book market. Did Bernardo Giunti adopt the time-consuming craft in use by growing colossus of publishing like Plantin?[28] If so, Bernardo Giunti did not merely and passively absorb Plantin's method. Rather he readapted it to his needs and somewhat advanced it. His multiple search tags and multiple organization of data that allowed to access information from different an-

[27] I should mention that this was the thought-provoking hypothesis that my friend and collogue Joran Proot proposed me during a post-conference walkabout in Milan, and I would like to manifest my gratitude to him.

[28] «Bernardino», Italian for little Bernardo, is the name that can be found in a beginning note that declares the legitimate property of the volume (YRL, Collection 170/622, f. 4r).

gulations did not find a parallel in the Plantin catalogue. Did Bernardo perfect the craft all alone? Possible, but not entirely credible.

Commonsense would suggest that compiling bibliographic catalogues for market assessment practices may have been a common drill among bookdealers whose ambitions were more than just modest. But to this day, the scarcely available sources suggest keeping this as a working hypothesis.

One conclusive statement would be that quali-quantitative computational search directories do not show up in the skillset outlined for beginner traders.[29] Then was this computational technique a secret of early modern book traders?

5. Ramifications

This essay has argued that early Renaissance and early Baroque printers had developed a technique to go around the risk of a growingly competitive market. The basis of this argument were two artefacts found in relevant cities of the book industry such Antwerp and Venice. By focusing mainly on the Venetian example, it has been contended that market risk calculation was a practice linked to a systematic compilation of bibliographic data that were flooding late Renaissance Europe. The hypothesis that is being suggested is that the growing competition created the pressure conducive to generate a systematic solution to a tangible problem. Meanwhile the information revolution brought forward by the printing press and the mechanical and quasi-industrial mindset of its key operators provided the fertile ground for this technical innovation in commercial bibliometric. Likely this rudimentary technique germinated in the environment of the print proto-industry. Ultimately, unlike all other commodities circulating in Europe, printed books were the first to carry unequivocal information on their production history. Such information was in full display on the title pages and colophons of most of the printed volumes. Censorial authorities often imposed printers to include precise information regrating authors, printers and publishers, along with the city and year of impression, to hold people accountable of the content of printed texts in circulation. The notion of a growing competition, already voiced by the very editions in circulation, was further amplified by the many printed sale catalogues circulating in Europe. However, if title pages, colophons and printed catalogues contributed to enhancing the notion of a growing competition among publishers, the information being so vascularly disseminated also provided the solution to prevent the trick of said competition. The mass of information traveling around Europe was ready to be diligently and orderly systematize in bibliographic repositories that could function as searchable directories of useful bibliographic information for strategic planning.

[29] A survey of the education of Italian merchants can be found in (Caracausi 2013).

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Produttività e crescita economica

Productivity and economic growth

Didier Boisseuil

La production d'alun en Occident: l'essor d'une industrie nouvelle à la fin du XV^e siècle

L'alun est une matière première qui intéresse depuis longtemps les historiens de l'économie. Produit de façon artificielle en grande quantité en Anatolie, dès la fin du XIIIe siècle, il fut longtemps commercialisé en Occident par les Génois, notamment Benedetto Zaccaria (Lopez 1933), ou par les Vénitiens, suscitant d'importants trafics, mobilisant de gros navires (Jacoby 2005). La poussée turque et l'affirmation de l'Empire ottoman contribuèrent à réduire ces échanges, sans toutefois les interrompre totalement (Jacoby 2005, 256 sq.). La découverte vers 1460, dans le Latium, à Tolfa près de Civitavecchia, d'un immense gisement d'alunite – l'un des minerais nécessaires à la production – suscita l'essor d'une ample industrie contrôlée par la Chambre Apostolique, jusqu'au début du XIXe siècle. Le commerce de «l'alun de Rome», organisé au profit des souverains pontifes et des grands marchands italiens – à commencer par les Médicis – a été particulièrement bien étudié par Jean Delumeau (Delumeau 1962); il a longtemps été interprété comme une forme précoce de monopole (Ait et Boisseuil 2014). Toutefois, la réalisation d'alun à la fin du XVe siècle ne s'était pas limitée au seul Latium, comme l'atteste des travaux, parfois récents (Dallai, Bianchi et Stasolla 2020). Dans maintes régions du bassin méditerranéen occidental (en Toscane, en Campanie, dans la péninsule ibérique…), d'autres sites de production ont vu le jour dès 1450 et surtout après 1470. Ils contribuèrent – au côté de Tolfa, qu'ils ne pouvaient égaler, toutefois – à approvisionner les grandes places commerciales européennes. L'essor de tous ces sites – ou alunières – a permis d'opérer, en quelques décennies, un véritable basculement de la production depuis la Méditerranée orientale vers la Méditerranée occidentale et a entraîné une modification des réseaux d'échanges (Boisseuil et Chareille 2023). Toutefois, les conditions de mise en œuvre de ces nouvelles infrastructures industrielles n'ont jamais fait l'objet d'études approfondies, malgré leur importance économique. C'est ce que je voudrais ici présenter, en tentant d'analyser les connaissances utiles[1] mobilisées pour initier et développer, avec succès, ces entreprises. Je commencerai par explorer les modalités de recherche déployées (notamment les lieux et les types de prospections envisagés), avant d'enquêter sur les techniques employées et les acteurs qui se sont efforcés de produire de l'alun, puis j'esquisserai une réflexion sur les structures entrepreneuriales qui ont contribué à l'essor de la production.

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[1] Pour une réflexion sur cette notion, cf. Berg 2007; Vivel 2020.

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Referee List (DOI 10.36253/fup_referee_list)
FUP Best Practice in Scholarly Publishing (DOI 10.36253/fup_best_practice)

Didier Boisseuil, *La production d'alun en Occident: l'essor d'une industrie nouvelle à la fin du XVe siècle*, © Author(s), CC BY 4.0, DOI 10.36253/979-12-215-0092-9.20, in Giampiero Nigro (edited by), *L'economia della conoscenza: innovazione, produttività e crescita economica nei secoli XIII-XVIII / The knowledge economy: innovation, productivity and economic growth, 13th to 18th century*, pp. 333-351, 2023, published by Firenze University Press, ISBN 979-12-215-0092-9, DOI 10.36253/979-12-215-0092-9

1. A la recherche de la pierre d'alun…

Alors que, dans la première moitié du XVe siècle, les sites de production orientaux en Thrace,[2] en Mer Egée à Mytilène/Lesbos (Arvanitidou 2020) et surtout en Anatolie à Phocée (Heers 1954), étaient exploités par des Génois, quelques marchands italiens se sont efforcés de trouver de l'alun, bien avant la chute de Constantinople. Ils semblent avoir initié leurs prospections dans les îles de la Méditerranée. Ainsi, dès 1402, Martin Ier accordait le droit de chercher de l'alun en Sicile à une poignée d'acteurs: Berto Belluni de Messines, Filippo de Aczano de Pouzzoles ou Andrea Carlino de Naples et le vénitien Disiato di Brolo (Dentici Buccellato 1984, 136-38). Un peu plus tard, à partir des années 1430, la République de Venise autorisait plusieurs membres de la famille Querini à prospecter en Crête (Jacoby 1987). En 1442, le florentin, Bernardo di Marco Salviati reçut le droit de produire de l'alun dans les possessions de l'ordre des Hospitaliers, en mer Egée.[3] Toutefois, il est probable qu'aucune de ces initiatives n'ait donné lieu à une véritable exploitation, puisque nous n'en avons pas trouvé trace jusqu'à présent. En revanche, il est certain que les recherches se poursuivirent et s'entendirent à la partie occidentale de la Méditerranée. À partir du milieu du XVe siècle, l'alun apparaît de plus en plus régulièrement, dans les concessions minières accordées par les différents États, comme une matière première que l'on cherche à produire, au côté des métaux et parfois des vitriols. Les plus anciennes mentions, à ma connaissance, remontent: à 1451, dans le territoire siennois notamment le mont Argentario (Lisini 1935 239-42), à 1461 dans le territoire milanais (Pipino 2009, 27), à 1463, dans le territoire florentin (Pampaloni 1975, 119-23), à 1468, en Provence (Coulet 1993, 287), à 1472, en Vénétie, dans le Val Camonica près de Brescia (Braunstein 1965, 549, 591). C'est aussi le cas dans la péninsule ibérique, la recherche est attestée: en 1461, dans le royaume de Valence (Cooper 2008, 321 sq.),[4] en 1462, à Paracuellos de Jiloca (Rubio Semper 1992, 199-201; Morales Gómez 2016, 543-569) et à Mazarrón en Murcie (Córdoba de la Llave, Franco Silva et Navarro Espinach 2005, 126), en 1469, dans le royaume du Portugal.[5]

Ces concessions s'accompagnèrent sans doute de prospections ou tentatives d'exploitation, même s'il n'est pas possible d'en trouver de nombreuses traces, notamment parce qu'elles ne furent pas toujours couronnées de succès, comme le suggèrent plusieurs auteurs qui les ont signalées. Ainsi, à Albarracín et à Ademuz, dans le royaume de Valence, les activités initiées en 1461 furent-elles vraisemblablement brèves voire infructueuses (Morales Gómez 2016, 553; Navarro Espinach et Villanueva Morte 2022, 99), peut-être un peu plus durable en 1465, dans le

[2] Mentionné encore en 1440 (Hocquet 2010, 92).

[3] A l'exception de Rhodes, où Zoan de la Rivera avait obtenu la même concession l'année précédente (Wright 2010).

[4] À Borriol, Artena et Orpesa ou Artemuz qui se trouve aux confins avec le royaume d'Aragon (Navarro Espinach et Villanueva Morte 2020, 123).

[5] «tirar e lavrar pedra-hume em todo o reino» (Peragallo 1907, 59 repris dans Guidi Bruscoli 2018, 70).

royaume de Castille, à Casacarrillo, près de Cornago dans la haute vallée du Douro (Cooper et Mirete Mayo 2001, 95). Dans le territoire génois, de vaines recherches furent engagées en 1465 (Pipino 2005, 75). Autour de Trévise, des découvertes sont mentionnées entre 1467 et 1472 (Pipino 2009, 28), mais elles ne paraissent pas avoir entraîné d'activité. En Toscane, deux découvertes sont signalées, sans résultats toutefois: en 1461, à Poggio Santa Cecilia,[6] et en 1473, à Boccheggiano dans les Monts Métallifères.[7]

Ces efforts – qui ont été davantage soutenus que suscités par les États – et ces échecs interrogent sur la façon dont furent entreprises les recherches. Il semble que les enquêteurs aient privilégié d'abord l'observation (des paysages, de la végétation, des terrains, des roches) et qu'ils aient recherché des lieux similaires à ceux exploités ailleurs, notamment en Anatolie ou en Mer Egée. Ainsi, Pie II rapporte-t-il dans ses *Commentaires* comment Giovanni da Castro, l'inventeur présumé de Tolfa, avait été attiré par la présence sur le site d'une végétation comparable à celles d'Asie.[8] Quelques années plus tard, en 1464, un citoyen siennois Francesco di Bartolomeo da Sant'Angelo se proposait de mener des recherches dans le territoire siennois, en considérant que certains endroits étaient similaires à ceux de Tolfa.[9] La démarche semble donc fondée sur l'analogie – un mode de raisonnement qui est commun au moyen âge.[10] Elle implique, toutefois, de la part des acteurs une connaissance des lieux antérieurement exploités. Elle explique peut-être aussi pourquoi les premières zones prospectées furent celles qui pouvaient rappeler les paysages insulaires ou côtiers orientaux, notamment le Mont Argentario,[11] l'île d'Ischia…[12]

Le succès de l'entreprise ne reposait pas seulement sur l'identification de similitudes. Car il fallait savoir où chercher et donc disposer d'une certaine familiarité – directe ou indirecte – avec les zones à observer. C'est pourquoi – comme pour toutes les autres prospections minières (Braunstein 1993; 2003a) – les enquêteurs s'appuyaient sur leur connaissance du terrain, quand ils étaient originaires de la région à explorer ou sur les compétences des autochtones. Ainsi, peut-on s'interroger sur les conditions de la découverte de Tolfa. N'a-t-elle pas été facilitée par le fait

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6 Archivio di Stato di Siena (ASS), *Statuti della città* 40, fol. 95v.

7 ASS, *Notarile antecosimiano* 687, acte du 26 avril 1473.

8 *Hic montes alti [Tolfa vetus] a mari introrsus recedunt silvis et aquis fecundi. Per quos dum Iohannes [Castrensis] ambulat, novam herbæ in montibus Asiae, qui Turchorum aerarium alumine ditant. Videt lapides albos et qui minerales apparent; mordet: salsedinem repperit; excoquit, experimentum facit: alumen producit (…) Vocati sunt artifices ex Genua, qui aliquando in Asia Turchi alumina tractavere. Li, cum loci naturam inspexissent, per omnia similem esse dixerunt Asiaticis montibus alumen ferentibus (…). Decoxere lapides, et alumen multo praestantius ac pulchrius exiit, quam illud Asiaticum. Missum est et ad Venetos et ad Florentinos, factum periculum; res ipsa opinionem superavit* (Pii Secundi 1993, 355-56).

9 «Exponsi con ogni debita reverentia per lo nostro fidelissimo servidore e cittadino Francesco di Bartolomeo da Sant'Agnolo, come da più tempi in qua et maxime da poi si scupererse l'allumiera de la Tolfa, lui ha certo per più parti del vostro contado, el quale in più luoghi pare conforme al detto paese de la Tolfa, se similie petrina et vena potesse trovare», ASS, *Consiglio generale* 230, fol. 195v-196; *Concistoro* 2155, fol. 39; *Concistoro* 588, fol. 35.

10 Sur l'importance de la notion d'analogie dans la pensée médiévale, cf. De Beaune, Hilaire-Pérez et Vermeir 2017, notamment p. 16-20.

11 Cf. *supra*, p. 260.

12 Cf. *infra*, p. 262.

que la famille maternelle de Giovanni da Castro était originaire de Corneto/Tarquinia (Sella 1944, 253; Caravale 1979; Ait 2009), à quelques kilomètres seulement des alunières? Peut-être connaissait-il déjà les lieux ou bien était-il capable de mobiliser des habitants susceptibles de le guider. C'est par exemple, dans un contexte proche, la démarche adoptée par un florentin pour engager des recherches dans le territoire siennois. En 1490, Tribaldo dei Rossi, un proche de Lorenzo dei Medici, se tourna vers les habitants du village de Magliano, à une centaine de kilomètres de Florence, pour obtenir des renseignements précieux sur la localisation d'une mine d'argent ancienne (Boisseuil 2019, 177-78).

Pour ce qui concerne l'alun, les experts locaux étaient peut-être informés de l'existence de dépôts d'aluns natifs ou de manifestations singulières – comme les sources thermales, les «soffioni», «bullicami» (Picon, Karadima-Matsa et Blondé 2016, 405-12; Di Nezza et Di Filippo 2020, 25-27; Dallai 2020, 117) – susceptibles d'indiquer la présence de gisements exploitables, puisque ces signes pouvaient être associés à la présence des roches alunifères.[13] Car ce sont bien des roches et tout particulièrement l'alunite, qui furent recherchées et principalement utilisées. En effet, nombre des gisements qui furent exploités et qui donnèrent naissance à des alunières étaient composés de ce minerai, notamment dans le Latium à Tolfa, en Toscane à Massa Marittima, Montioni et Monterotondo Marittimo, en Campanie à Agnano et Ischia, en Murcie à Mazarrón (Picon, Karadima-Matsa et Blondé 2016, 411; Dallai 2020, 117; Martínez Alcalde 2020, 186). Néanmoins, les gisements qui furent mobilisés au moyen âge ne sont pas tous actuellement identifiés et il est probable que d'autres roches alunifères ont été employées avec plus ou moins de succès – comme la jarosite à Casacarrillo (Cooper et Mirete Mayo 2001, 103).[14] De même, l'ampleur et la qualité intrinsèque des gisements pouvaient avoir des conséquences sur l'issue du processus de production. C'est pourquoi, les inventeurs mobilisaient leurs sens (Fritz et Duhl, 2016) et opéraient des essais – comme pour les minerais métalliques (Braunstein 1993 ; 2003a). Ainsi, Giovanni da Castro goûta-il, d'après Pie II, le minerai de Tolfa, et l'expérimenta.[15] Selon le chroniqueur génois Agostino Giustiniani († 1536), Bartolomeo Pernice, après l'avoir identifié, testa lui-même le minerai du gisement d'Ischia.[16] C'est donc tout un ensemble de connaissances utiles, fondées sur des savoirs pratiques (comme l'expérimentation[17]) qui fu-

13 Même si – bien que rien ne l'atteste – on puisse concevoir, dans certaines régions, une pratique ancienne de production d'alun d'alunite, mais à une autre échelle, modeste (Picon, Karadima-Matsa et Blondé 2016, notamment 410-11).

14 Pour un aperçu plus vaste des minerais exploités en Espagne, cf. Martínez Alcalde 2020, 184-86.

15 Cf. *supra* note 8.

16 «Per questi tempi [1459] Bartolomeo Pernice, mercadante Genovese navigando in cerco l'Isola di Enaria ossia d'Ischia conobbe che nella piaggia erano molti scogli aluminosi, cioè atti per fare alume, e pigliò parte di quelli e li fece cuoecere in la fornace, e riuscitte alume ottimo; e così Bartolomeo della città di Rocco di Soria, dove aveva negoziato più anni, revocò in Italia l'arte di fabbricare l'alume, la quale già per gran spazio di tempo era morta e stata intermessa» (Giustiniani 1854, II, 418).

17 Sur l'importance de l'expérimentation dans le développement des techniques, cf. Chandelier, Verna et Weil-Parot, ed. 2017.

rent donc intensément sollicitées pour découvrir des gisements exploitables et pour créer des alunières.

2. L'essor des alunières occidentales

Ces initiatives aboutirent rarement avant 1460 et surtout 1470. Le premier site exploité en Occident fut celui proche de la Solfatara, à Agnano dans les Champs Phlégréens, actif au moins en 1452, partiellement détruit par un tremblement de terre en 1456, avant de reprendre en 1462.[18] En Sicile, l'activité débuta d'abord à Paterno, en 1458 et par la suite à Fiumidinisi jusqu'en 1466 (Campagna 2020, 1084). C'est probablement en 1458-1459 aussi, que commença l'activité sur l'île d'Ischia.[19] Le minerai extrait des îles de Vulcano et Lipari était exporté pour être traité en Sicile, entre 1460 et 1461 (Pipino 2009, 28).[20] C'est à cette époque que débuta l'exploitation à Tolfa (avec les premières carrières)[21]. L'activité dans la Maremme et les Monts Métallifères fut plus tardive: l'alunière de Sasso fut créée en 1470 – mais elle fut abandonnée avant 1476[22] –, celles de Massa Marittima et de Monterotondo

[18] Pour sa localisation cf. Picon, Karadima-Matsa et Blondé 2016, 411. Il fut visité par le roi Alphonse 1er d'Aragon, (Feniello 2003, 158; 160).

[19] Sans doute un peu avant, selon le témoignage rapporté par Gaetano Cestari, d'un certain Pietro Lupo. «In tempo di Re Alfonso I o vero ne la intrata di Re Ferrante I [donc à partir de 1458] da qual tempo in qua fo introducta in Iscla & Pezuolo exercitio de fare dicto alume & miniere, de qua per un genoese fu optenuto privilegio dali dicti Signuri (…) che dicto genoese se chiamasse Bartholomeo Pernice» (Cestari 1790, 20). L'alunière d'Agnano étant en activité depuis le début des années 1450, il est possible que l'initiative de Bartolomeo Pernice concerne essentiellement Ischia, même si on ne peut exclure totalement qu'il ait initié aussi celle d'Agnano. Pour la discussion de cette éventualité, cf. Pipino 2009, 24-25.

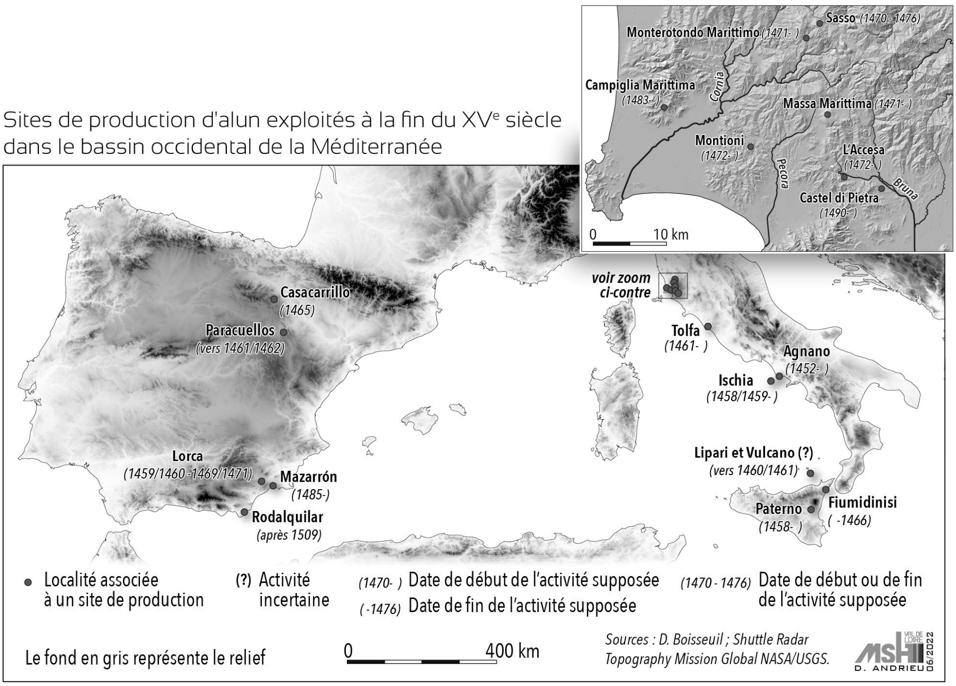
[20] La production semblait modeste et incertaine comme l'atteste une lettre du 19 juin 1463 de Piero di Dietisalvi, depuis Lipari à Giacomo Acciaiuoli: «Io sono stato alla lumera parechi dì et ò voluto intendere in quello consisteva et di quello ò compreso non scripto alla M[aes]tà del Signor Re, ò trovato che perfino a questo dì ànno lavorato circa 60 cantara d'allume che è una fraschame, ò trovato che a detto allume abino dato credito nullo et non sanno loro se l'à avere; io gli ò sollecitati che ne voglino mandare di fori in modo che una volta intendino dove si truova questa cosa in fare, n'ànno mandato la metà di questo alle galee venitiane che vanno in Aqua Morta che lo porteranno et intenderanno che credito abia avere et questo resto manderanno a Venezia et attenderanno la risposta, che fra 3 o 4 mesi l'aranno, et secondo l'aranno si governeranno; in questo mezo lavoreranno per non dimonstrare di starsi ma andranno ratenuti. Se intendono che detto allume abia uscita qui, si dimonstra materia assai da farne et con poca spesa. Siché io faccio pensieri stare patiente fino a quel tempo et tanto che vegha ordinata la cosa e poi farò pensieri levarmi di qua». Biblioteca Nazionale Centrale di Firenze, *mss* II-IV-416, fol. 30-30v. Selon Marie-Louise Heers, l'un des acteurs de ce commerce sicilien à Gènes était le florentin Andrea Fattini (Heers 1954, 52).

[21] Plusieurs indices laissent penser que l'activité débuta courant 1461. Une première concession accordée à Giovanni da Castro et à ses parents par la commune de Corneto date, en effet, du 30 avril 1461 (Sella 1944, 252). L'activité du port de Civitavecchia augmenta considérablement à partir de la fin de l'hiver 1461 (Vaquero Piñeiro 2004, 183). Voir aussi Boisseuil, Chareille et Ait 2023.

[22] Déjà en 1473, le minerai n'était plus considéré comme exploitable, comme l'atteste une lettre adressée à Laurent de Médicis par Lutio Giugni depuis l'alunière, datée du 10 août 1473, «Io credo abiate sentito da mie' fratelli e simile da Antonio Baldinotti iscrivano da questa lumiera della qualità di che è tornata la pietra, el pocho frutto ne sie e simile di 2 monti de' tre dove si togliava quando Bernardo de Lucro ci fu», ASF, *Mediceo Avanti il Principato*, filza XXIII, n°544.

l’année suivante, en 1471 puis celles de Montioni et de l’Accesa en 1472, enfin celle de Campiglia Marittima en 1483, celle de Pietra (Castel di Pietra) plus tardivement en 1490 (Boisseuil 2014; Boisseuil 2005, 106-07). En Espagne, plusieurs sites furent brièvement exploités: à Paracuellos, vers 1461-1462 (Morales Gómez 2016, 543-569), voire à Casacarrillo en 1465 (Cooper et Mirete Mayo 2001, 95) et sans doute Lorca entre 1459 et 1460, puis 1469 et 1471 (Navarro Espinach et Villanueva Morte 2020, 125); d’autres furent plus intensément utilisés comme Mazarrón après 1485 (bien que la première concession date de 1462, cf. *supra*) et Rodalquilar plus tardivement au XVI[e] siècle (Igual 2014; Navarro Espinach et Villanueva Morte 2020, 127). On aboutit donc avant 1500 a près d’une quinzaine de localités, comprenant un ou plusieurs sites plus ou moins intensément et durablement exploités, dont la plupart sont postérieurs à 1460 (Fig. 1).[23]

Fig. 1. **Sites de production d’alun exploités à la fin du XV[e] siècle dans le bassin occidental de la Méditerranée**



La multiplication des prospections et l’invention des sites ne sont donc pas directement liées, à la chute de Constantinople et à l’avancée de l’Empire ottoman, mais semblent davantage corrélées aux difficultés d’approvisionnement. Vers 1460, les stocks disponibles des Occidentaux en Orient paraissaient épuisés (Heers et de

[23] Rares sont les sites actuellement identifiés: un seul d’entre eux a été fouillé (Monterotondo) quelques *survey* ont été réalisés ailleurs (Dallai, Bianchi et Stasolla 2020).

Groer, ed. 1978, 375).[24] Certains sites de production comme ceux de Lesbos/Mytilène étaient à l'arrêt,[25] mais les trafics n'étaient pas totalement interrompus notamment entre l'Anatolie et Venise.[26] Le prix de la matière première semble avoir augmenté.[27] En outre, les premières découvertes occidentales ont probablement joué un rôle d'entraînement. Car le risque de voir certains fournisseurs disposer d'une position dominante – voire monopolistique – semble avoir suscité l'invention de nouveaux sites ou la reprise d'activités plus anciennes. Ainsi, l'essor de Tolfa peut-il avoir encouragé la reprise d'Agnano, attestée en 1462 (Feniello 2003, 162). Il est clairement établi comme un moteur des prospections en Toscane.[28] Toutefois, la création d'un cartel entre le roi de Naples et le pape – une *maona* – en 1470,[29] pourrait bien avoir aussi suscité l'essor des alunières dans la région.

Quoi qu'il en soit, ces entreprises – lorsqu'elles étaient actives – semblent avoir rapidement été productives. À Tolfa, quelques mois après l'invention du site (probablement en 1460 ou au début de 1461, cf. *supra*) les premières tonnes d'alun étaient commercialisées: dès septembre 1462, la Chambre Apostolique passait contrat avec des commerçants génois et l'année suivante, avec les Médicis (Zippel 1907, 16, 19). L'alun de Mazarrón était commercialisé en Flandres en 1486-1487, alors que l'activité ne débuta vraiment que vers 1485 (Munuera Navarro 2020, 144). C'est le signe que les techniques mobilisées étaient bien rodées ou furent facilement adaptées. Elles sont connues à travers quelques textes – notamment Francesco di Balduccio Pegolotti pour Phocée (pour le début du XIVe siècle), Vannoccio Biringucci dans son *De la Pirotechnia* publié de façon posthume en 1540 – et le procédé mis en œuvre a été analysé de façon détaillée par Maurice Picon (Picon 2000). Ce dernier distingue deux moments principaux (la calcination et la lixivation) et deux types de fours: les premiers pour cuire la pierre, comparables à des fours à chaux, les seconds pour accueillir des chaudières métalliques. Quelques rares données archéologiques (Dallai et Martínez Alcalde 2022) – et quelques documents écrits (Boisseuil et Chareille 2009) – laissent entrevoir ces infrastructures. Les fouilles menées par Luisa Dallai et ses collègues à Monterotondo ont mis à jour une batterie de fours de calcination datés de l'extrême fin du XVe et du début du XVIe siècles et deux fours de lixivation (Dallai et Poggi 2012; Dallai 2020). Ces derniers ne sont pas sans rappeler par leur forme et leur dimension, des vestiges observés à Ischia (Fineschi 2020) et surtout à Lesbos (Arvanitidou 2020). Ces similitudes laissent entrevoir – à défaut d'une analyse comparée poussée – des procédés semblables. Elles suggèrent de possibles transferts techniques depuis les rives orientales jusqu'aux

[24] Marie-Louise Heers soutient que les aluns orientaux et notamment les stocks de Chio étaient épuisés en 1458 (Heers 1954, 38, 52).

[25] À l'inverse, certains sites anatoliens étaient encore actifs.

[26] David Jacoby assure les routes des aluns anatoliens étaient encore ouvertes à la fin du XVe siècle (Jacoby 2005, 254-56). Encore au début du XVIe siècle, les Vénitiens s'approvisionnaient en Orient (Gilbert 1991, 37), même s'ils utilisaient aussi de l'alun de Tolfa (Boisseuil, Chareille et Ait 2023).

[27] À Sienne, les prix évoluèrent à la hausse à partir de 1460 (Giacchetto 2023), mais aucune enquête systématique sur le commerce de l'alun ne vient confirmer cette donnée.

[28] Cf. note 9.

[29] Sur la création de cette société commune, cf. *infra* et Feniello 2003, 163.

terres occidentales.[30] Il convient de rester prudent cependant, car les infrastructures italiennes et espagnoles ne nous sont pas toutes connues et les rares observations menées (à Monterotondo, à Mazarrón) montrent qu'elles ne furent pas uniformes ni même durables sur chacun des sites. Il faut supposer des adaptations en fonction notamment du minerai employé et de la disponibilité en matières premières: l'alimentation en combustible et en eau – que l'on perçoit mal pour les quelques sites identifiés – ont pu conditionner le gabarit des réalisations, suscité des aménagements, voire des innovations techniques que nous ne percevons pas.

Néanmoins, il existe un autre biais qui permet d'envisager l'existence d'une circulation de savoirs techniques, c'est le rôle joué par quelques acteurs privilégiés, principalement des Génois, dans l'essor de la production d'alun en Occident. L'un d'entre eux mérite une attention toute particulière: Bartolomeo Pernice (ou Pernix). Il était impliqué dans la vie politique ligure, puisqu'il fut membre du Conseil des Anciens, en janvier 1460,[31] même s'il n'appartenait pas à l'une des familles les plus puissantes de Gênes au XVe siècle.[32] Il aurait vécu à «Rocca di Soria» – probablement Raqqa de Syrie, c'est-à-dire Edesse (Testi 1931, 444) –, où il aurait pratiqué le commerce.[33] En tout cas, il navigua et fut présent dans plusieurs des lieux où fut recherchée et parfois trouvée de l'alunite et lancée la production. En 1438, il obtint, ainsi qu'Andrea Imperiali, un sauf-conduit pour commercialiser avec les Siennois.[34] En 1451, il fut autorisé à prospecter sur le Monte Argentario.[35] Il est réputé avoir découvert le site d'Ischia, vers 1458-1459.[36] En 1463, il était autorisé – après son échec sur le Monte Argentario – à prospecter dans le territoire siennois pour trou-

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[30] Cette circulation des acteurs et des modèles d'infrastructures peut être soutenue par une brève allusion d'un citoyen de Volterra, Gentile Guidi, dans une lettre adressée à son frère, Mercatante, installé à Florence et datée du 1er avril 1435, où il rapporte, concernant la production de soufre et de vitriol qu'ils déténaient ensemble dans le sud du territoire de Volterra, «Qua sento e riviato alle chave [di zolfo], uno del Reame de Puzuolo di Napoli e pare chapitasse costi a te e che tu lo inviassi qua a me; non fece molto, è andato la e molto dritamente, à voluto vedere ogni cose, e preso misure di fornaci e di vaschi in modo ne ito molto contento, e mi guasto il mio disegno: mio pensiero era andare una volta a Pozuolo», ASF, *Archivio Guidi* 581, fasc. 2.

[31] Toutefois, il ne siégea pas, probablement parce qu'absent, Archivio di Stato di Genova (ASG), Archivio Segreto, *Diversorum Comunis Ianue* 3044, Acte du 22 janvier 1460.

[32] Mais présente au XVIe siècle – après la réforme d'Andrea Doria de 1528 – parmi les membres de l'Albergo des Lercari. Je souhaite remercier ici Denise Bezzina pour cette précision.

[33] Cf. note 16.

[34] Le 11 février 1438 (ns), *Domino Bartolomeo Pernice et domino Andree Imperiali, omnibus de civitate Genue mercatoribus et unicuique ipsorum coniuctum vel separatim et de per se cum ipsorum et cuiuslibet ipsorum mercantiis omnibus ac bonis et navi et etiam personis cunctis super ipsa existentibus, concessus est salvusconductus per tempus unius mensis proxime secuturi*, ASS, *Concistoro* 1650, fol. 15r.

[35] Le 15 juin 1451, «In prima, che a decto Bartholomeio Pernixe suoi compagni e successori loro sia lecito liberamente per via d'allogagione potere pigliare, trovare e cavere per se e per altri suoi lavoranti, famegli e compagni nel Monte Argentario, isole di mare di nostro comune e in ogni altro luogo del contado, iursidictione e distretto di Siena, excepto che nel terreno e corte di Massa, ogni e ciascuna vena e minora d'ogni metallo, come è d'oro, d'arento, ferro, rame, argento vivo, stagnio, piombo e altre vene come è pietre d'ogni colore da fabricare chiese e fare musaichi, allume, terra da salnitro e vetriuolo», A.S.S. Concistoro 2118, fol. 40r-41r; A.S.S. *Consiglio generale* 225, fol. 174r-175v. Publié dans Lisini 1935, 239-42.

[36] Cf. note 16.

ver des mines d'alun avec deux associés siennois: Mino di Guido Tholomei et Francesco di Giacomo Pepi detto Germano.[37] Sa compétence était reconnue, puisqu'en 1465, il fut rétribué par la Chambre Apostolique pour avoir essayé l'alunite de Tolfa dans l'un des fours de calcination.[38] Quelques mois plus tard en 1465-1466, il était à Lucques et demandait à la Commune, de pouvoir chercher des minerais – dont l'alun – sur son territoire.[39] En presque trente ans, il semble avoir acquis une expertise reconnue et joué un rôle dans l'essor de l'industrie de l'alun entre la Campanie et la Toscane.

Il ne fut pas le seul Génois à se lancer dans la production d'alun en Occident. Son compatriote Damiano Spinola qui trafiquait entre la Sicile et la Toscane – vers 1458, il exportait des fruits secs vers Porto Pisano (Ouerfelli 2008, 454) – participa à l'essor des alunières de Sicile, sans que l'on puisse déterminer son rôle exact (Pipino 2009, 28; Campagna 2020, 1084). En revanche, on perçoit mieux, la fonction de Biagio di Centurione Spinola puisqu'il fut le *principalem magistrum dicte minerie aluminum* c'est-à-dire le responsable de la production des alunières de Tolfa, engagé dès le mois de juin 1462 par la Chambre Apostolique à raison de 400 florins par an et ce jusqu'en 1467 (Zippel 1907, 16; Ait 2010, 248). Un autre de ses concitoyens occupe cette même fonction, l'ex-doge de Gênes, Ludovico Campofregoso, engagé

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[37] «Perché altra volta nel 1451, esso Bartholomeo (…) havendo esso dirizato el suo primo oggieto et pensiero al Monte Argentario dove aveva trovato la vena del ferro et del argento et d'altre cose; et sopravenendo la guerra del duca di Calabria, poi del conte di Pitigliano et quella del conte Iacomo, non pote seguire suo disegno et adviso et conveneli andare in altre parti a procacciare sua ventura (…); el detto Bartholomeo per se et suoi participi et compagni li sia concesso (…) di potere cavare et fare cavare, lavorare allume et minere d'allumi in quegli luoghi del terreno et distrecto di Siena dove li parrà et li piaccia», ASS, *Consiglio generale* 229, fol. 293-295v. Cité dans Piccinni 1999, 245; publié Boisseuil 2005, 113-115.

[38] Suivent les écritures sur différents feuillets des livres de comptes conservés pour l'administration des alunières de Tolfa: «Bartolomeo Pernice da Genova de dare a dì 26 di marzo 1465, per alumi in monte et per allumi la Camera li detti per un dono per la prova fece della pietra dello allume, a k. 10, … cantara 25», Archivio di Stato di Roma (ASR), *Camerale III* reg. 2378 (fasc. A), fol. 11. «A dì 26 di marzo [1465], cantara vinticinque d'alume levato della sua lumera [Bartolomeo Framura] per messer Bartolomeo Pernice a conto della Camera Apostolica in questo, c. 228… cantara 25», ASR, *Camerale III* reg. 2378 (fasc. D), fol. 225. «A dì XXVI di marzo [1465], cantara vinticinque d'alumi consegnato per essa [Camera Apostolica] a messer Bartolomeo Pernice, della lumera di messer Bartolomeo Framura per la sua fatiga della sperientia fe della pietra dele fornace che ne fe alume. Lo quale alume sopra decto li fo decti per vigore de uno a mandato de mons*ignor* el tesariero della Sanctità de N.S. facto de dì XV de marzo 1465 a conto di messer Bartolomeo in questo … c. 225, cantara 25», ASR, *Camerale III* reg. 2378 (fasc. D), fol. 227v.

[39] Le 19 septembre 1465, *auctoritas componendi pro metallis et alumina fodendis. Item fuit propositum quod quidam Bartolomeus Pernice obtulit Magnificis dominis velle invenire et fodere in districtu lucano multas manieres metallorum et aluminis et aliarum rerum cum certis pactis et capitulis que annotavit*… Archivio di Stato di Lucca (ASL), *Consiglio Generale* 19, fol. 103; le 29 avril 1466, *per mineriis fondendi*, «Expone con ogni debita reverentia, lo vostro fidelissimo servitor Bartolomeo Pernixe cittadino di Genova e dice come lui hae già fa circa mesi sei proximamente passati, praticato con li Magnifici Signori che dicto tempo sono seduti circa le maniere delli septe metalli, alumi, vetrioli, salnitri, sal amoniaco et ogni maniera che si trovasse sopra terra o sotto terra paleze overo secreta di potere fare cavare in nello vostro territorio per se o per altra persona che volesse per lui cavasse, et questo per anni X proximi avenire dal di che si farà di tal cosa rimaso d'accordio francamente libere et sicure sensa pagare alchuna cosa etc». ASL, *Consiglio Generale* 19, fol. 179-1.

pour diriger l'alunière de l'Accesa, près de Massa Marittima, en 1471 (Boisseuil 2014, § 12). Il est étonnant qu'un prince puisse assumer cette fonction, mais le contrat d'engagement précise qu'il n'interviendrait pas seul. Comme il avait épousé Ginevra Gattilusio, la fille de l'un des derniers seigneurs des îles de la mer Égée (Wright 2014, 181), il est possible qu'il ait été accompagné d'ouvriers ou de techniciens capables de faire fonctionner les fours provenant de cette partie orientale de la Mediterranée.[40] Des Génois apparaissent aussi en Espagne, mais plus tardivement. Les frères Rey, Baltasar, Luis et Domingo, bien implantés à Valence, furent chargés de produire de l'alun à Mazarrón probablement dès 1485.[41] Le rôle joué par les acteurs ligures – notamment les membres de familles puissantes, comme les Spinola, Campofregoso – suggère qu'ils ne se contentaient pas seulement du transport de l'alun oriental, comme ils l'avaient fait au cours des siècles précédents au côté des Vénitiens, mais qu'ils avaient une réelle connaissance des modes la production ou une capacité à les dominer.

Cependant, ils ne monopolisèrent pas ces savoirs – ou n'y parvinrent pas –, car nombre d'autres techniciens furent à la tête d'alunières (Arnoux et Monnet, ed. 2004; Boisseuil 2016). En Toscane, le *conductor* de l'alunière de Monterotondo en 1471 était un citoyen siennois, Bartolomeo di Mariano Allegretti (Boisseuil 2014, § 11), et quelques années plus tard, en 1507, ce fut le fils bâtard d'un grand médecin, Piero di fu Alessandro da Sermoneta (Boisseuil – Chareille 2009, 14). Francesco di Giacomo detto Germano, qui fut l'un des associés Bartolomeo Pernice en 1463 (cf. *supra*),[42] était considéré comme *magister lumerie* et intervint sur plusieurs des sites toscans (Boisseuil 2014, § 11).[43] À Agnano, la reprise de l'activité fut assurée en 1462, par un technicien de renom, Guglielmo Lo Monaco (Feniello 2003, 162; Feniello 2005, 199 sq.), qui était au service des Aragonais.[44] En Espagne, la responsabilité technique paraît plus incertaine: Juan de Casal (ou Casals) fut reconnu comme *magister aluminis de roqua* pour tout le royaume d'Aragon et de Valence; il travailla notamment à Ademuz en 1461 et à Paracuellos de Jiloca en 1462, avec un succès mitigé.[45] Ces techniciens n'avaient pas nécessairement une connaissance directe des modes de production orientaux, mais grâce à l'ampleur de leurs compétences techniques, organisationnelles, ils furent capables de mettre en œuvre une production nouvelle. Le succès de leurs activités témoigne, s'il était encore nécessaire de le rappeler, de l'importance de la circulation des savoirs techniques et du rôle des appren-

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[40] D'autant qu'il s'était proposé, étant doge, de soutenir les responsables de la «maona de Chio» après la prise de Lesbos en 1462 (Argenti 1958, 242).

[41] Le contrat d'engagement date de 1486, pour 6 ans, mais c'est un renouvellement (Franco Silva 1995, 105; Igual Luis 2014).

[42] Ce rapprochement suggère une véritable communication dans le monde du travail (Braunstein 1992; Braunstein 1999).

[43] Il était aussi proche des Allegretti.

[44] Sur le personnage, cf. Barreto 2011.

[45] Morales Gomez 2016, 546, 548. Peut-être était-il originaire d'une famille de marchands lombards présents à Valence dans la première moitié du siècle (Navarro Espinach et Villanueva Morte 2020, 127).

tissages et des savoirs tacites,[46] parmi les connaissances utiles dans l'essor artisanal et industriel de la fin du moyen âge. Il suggère davantage de coopération que de concurrence et une forme de libéralité dans la mise à disposition des procédés techniques.[47] Il confirme aussi l'importance des centres urbains (comme Sienne) et des districts industriels comme foyers essentiels de la réception ou de la diffusion de ces savoirs. Surtout, la rapidité de circulation, d'adaptation de ces savoirs souligne le caractère étroitement connecté de ces espaces (entre la Campanie et la Catalogne), par le biais de la mer Tyrrhénienne notamment, particulièrement fréquentée par les marchands génois, toscans et catalans. Ce sont d'ailleurs, des marchands qui ont contribué à fonder, même s'ils ne furent pas seuls, plusieurs des alunières, selon des structures entrepreneuriales, très différentes les unes des autres, néanmoins.

3. Des entreprises industrielles dirigées par des marchands

La principale de ces entreprises était celle de Tolfa dont l'organisation est singulière. La production fut lancée – sous le contrôle technique de Biagio di Centurione Spinola (cf. *supra*) – par trois associés, désignés comme *constructores*: outre Giovanni di Paolo di Castro (Ait 2009), deux marchands l'un génois, Bartolomeo Framura et l'autre pisan, même si installé depuis longtemps à Viterbe, Carlo Gaetani.[48] Les trois s'étaient engagés, vraisemblablement dès 1462, auprès de la Chambre Apostolique à fournir plus de 30 000 cantares d'alun par an (environ 1500 tonnes).[49] On ignore encore comment s'organisait concrètement la production – notamment l'emplacement des premiers des fours de calcination et de lixivation – mais il existait plusieurs zones d'extraction (Vallelonga 2020). Néanmoins chacun des trois associés était responsable de ses ouvriers et devait stocker l'alun produit dans ses propres magasins à Civitavecchia (Zippel 1907, 22), dont l'enregistrement et le transport étaient assurés par des représentants de la Chambre Apostolique – ou bien entre 1465 et 1471, par les Commissaires de la Croisade.[50] En 1465, la filiale romaine de la banque Médicis obtint la «depositeria» de la Chambre Apostolique et celle du Trésor de la Croisade (Zippel 1907, 403). *In fine*, l'alun acheté par le dépositaire était commercialisé en exclusivité par une société fermière[51] – les Médicis jusqu'en 1476[52] –, mais les producteurs pouvaient aussi écouler leurs excédents en les

[46] Sur la circulation des savoirs techniques et des savoirs tacites, cf. Braunstein 1999; Hilaire-Pérez et Verna 2006; Pérez et Verna 2009.

[47] Plus précisément dans la péninsule italienne à la fin du moyen âge, voir Epstein et Fava 2009; Donati et Franceschi 2018.

[48] Sa descendance était apparentée aux Margani (Ait 2010).

[49] Nous ne connaissons que le renouvellement du contrat qui date de 1465 (Zippel 1907, 21).

[50] En 1465, Paul II institua en effet, que les revenus du commerce de l'alun seraient destinés à financer la Croisade contre les Turcs et géré par une Commission composée de trois cardinaux (Zippel 1907, 24; 416; Weber 2013). Sixte IV remit la gestion des alunières de la Croisade aux mains de la Chambre Apostolique, en 1471 (Zippel 1907, 24; 418).

[51] Le premier contrat de "l'appalto" date novembre 1462, le second du 20 mars 1465 (Rinaldi 1995, 15; 20).

[52] Puis confiée aux Pazzi (Zippel 1907, 404).

vendant de façon préférentielle à la papauté, en les faisant vendre par la société fermière ou en assurant eux-mêmes leur exportation (Boisseuil, Chareille et Ait 2023). Pour autant que l'on puisse en juger (car les documents sont peu nombreux), le système évolua peu avant la fin du siècle,[53] seuls quelques acteurs changèrent. Les Médicis remplacèrent Bartolomeo Framura au sein de la société productrice en 1466 (Zippel 1907, 404), Carlo Gaetani céda la place à son fils, Alfonso en 1479 (Zippel 1907, 424).[54] Les Médicis furent évincés de la ferme en 1476, au profit des Pazzi, jusqu'en 1478, puis se succédèrent: Visconte Cigala et Domenico Centurione, de nouveau les Médicis (1485-1489), les génois Niccolò et Paolo Gentili (1489-1491) et à partir de 1492, le florentin, Paolo Rucellai (Delumeau 1962, 89-90). La production et la commercialisation semblent avoir été importante, tout au moins pendant la période où les Médicis contrôlèrent la ferme du commerce des aluns :[55] il est probable qu'elle excédait les demandes pontificales contractualisées.[56] Les pratiques marchandes – comme savoirs utiles – ont sans doute participé au succès et à la continuité de l'entreprise pontificale.

On connaît moins bien le fonctionnement de la société qui assurait la production d'Agnano, mais en 1462, elle apparaît comme une 'joint venture' entre Guglielmo Lo Monaco et Ferrante d'Aragon qui n'entra en action que trois ans plus tard (Feniello 2003, 160; Feniello 2005, 199).[57] En juin 1470, afin de limiter la concurrence, le pape proposa de réunir la production des alunières de Tolfa à celle du royaume de Naples en ne formant plus qu'un seule «maona» (Zippel 1907, 35; Delumeau 1962, 24-26; Feniello 2003, 162). Cette dernière ne dura pas plus d'un an et la production d'Agnano se maintint sans doute modestement par la suite.[58] En revanche, il semble bien que l'alunière d'Ischia ait davantage produit. Le souverain y joua un rôle moindre. Sous la direction de nombreux concessionnaires, proches des Aragonais: d'abord des marchands vénitiens résidant à Naples, puis le comte de Sarno (1481-1486). Avec l'activité de plusieurs sous-traitants napolitains (Gaspare Scozio, Aniello Pierozzi) la production se maintint et était exportée (Feniello 2003, 163).[59] La quantité d'alun produit à Lipari était sans doute modeste malgré les efforts de quelques marchands florentins.[60] Les alunières espagnoles, lancées par des

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[53] Il faut attendre la gestion d'Agostino Chigi au début du XVI^{e} siècle, pour observer un changement dans le mode de production (Ait et Modigliani 2021).

[54] Une fois mort, la gestion de l'alunière revint aux Margani puisque Alfonso Gaetani avait épousé Cristofora Margani (Ait 2010, 248).

[55] C'est la seule période de la fin du XV^{e} siècle, pour laquelle sont conservées, déposées à l'ASR, des épaves archivistiques de cette vaste entreprise (Boisseuil, Chareille et Ait 2023).

[56] Carlo Gaetani aurait produit à lui seul pendant les années 1464-1465, près de 70 000 cantares d'alun (Ait 2010, 249).

[57] Le contrat prévoyait la réalisation de 7 fours pour cuire la pierre et d'un édifice pour la lessiver. Guglielmo s'engageait à produire 2400 cantares/an (Cestari 1790, 26-31).

[58] Elle paraissait modeste au regard de Tolfa: 200 cantares par mois (Zippel 1907, 37; Feniello 2005, 205).

[59] Des outillages et chaudières neufs furent installés en 1473 (Feniello 2005, 203). Voir aussi Pipino 2009, 29-30.

[60] Cf. note 20.

marchands locaux, furent peu productives,[61] à l'exception de celle de Mazarrón. Cette dernière avait été concédée par Henri IV, à son favori Juan Pacecho, marquis de Villena en mai 1462 qui s'était très vite associé en 1463 à Pedro Fajardo, officier de justice. Les deux protagonistes se réservaient, pour moitié chacun, l'alun produit et cédaient à un exploitant la production. Le contrat qui intéressait leurs héritiers respectifs fut reconduit en 1480, à la suite du renouvellement de la concession royale. Il est possible que l'activité ait débuté alors. Elle fut d'abord confiée à un groupe d'acteurs locaux originaires de Murcie, mais en 1485, ils furent évincés au profit des frères Rey, des Génois, qui s'engageaient à produire 4000 cantares d'alun par an (Franco Silva 1995, 105; Córdoba de la Llave, Franco Silva et Navarro Espinach 2005, 127-128). C'est à partir de cette époque que l'alun était exporté à Valence (Igual Luis 2014) et jusqu'en Flandre.

On connaît mieux les sociétés qui œuvrèrent en Toscane. Elles étaient composées, surtout après 1480, de plusieurs investisseurs appartenant aux élites politico-économiques, essentiellement siennoises – plusieurs membres de familles influentes comme Borghesi, Tolomei, Petrucci et bancaires comme Pini, Spannocchi – et dans une moindre mesure, florentines – Médicis et Capponi (Boisseuil 2014, § 10 sq). Par leur structure, ces entreprises étaient comparables aux compagnies commerciales. Elles s'acquittaient envers les autorités publiques – seigneur de Piombino, communes de Sienne, de Volterra, de Massa Marittima… – d'un droit d'exploitation (sous la forme d'une location) et commercialisaient directement la production, par l'intermédiaire des réseaux d'affaires qu'elles connaissaient ou animaient. Même modeste au regard de Tolfa, la production trouvait ses débouchés (locaux, internationaux). Ainsi, l'alun de Piombino voyageait-il jusqu'à Valence, en Espagne, et même jusqu'en Flandres ou en Angleterre.[62]

Il est difficile de savoir, faute de documents,[63] si les formes organisationnelles[64] déployées dans les alunières occidentales, étaient de beaucoup différentes de celles mobilisées par les Génois auparavant en Orient et si les pratiques comptables communes à tous ces acteurs économiques de premier plan (marchands et banquiers toscans notamment) ont joué un rôle important dans l'essor des entreprises européennes. Néanmoins, elles pouvaient apparaître comme des connaissances utiles qui furent, à l'égal des savoirs techniques empruntés ou adaptés, des connaissances empiriques collectées rapidement,[65] nécessaires pour créer, en une décennie environ (entre 1460 et 1470) des industries nouvelles et viables.[66] Ces alunières ont

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[61] Une cinquantaine de quintaux annuels pour Paracuellos à la fin du siècle (Morales Gomez 2016, 550). En 1462, deux chaudières de bronze sont attestées à Paracuellos (Navarro Espinach et Villanueva Morte 2020, 126).

[62] Notamment en 1485-1486, à raison de plusieurs milliers de cantares par chargement, cf. ASF *Notarile antecosimiano*, 18577, fol. 10v-11r, 48v, 113-114v, 131r.

[63] On a jusqu'alors repéré qu'une seule comptabilité d'alunière, datée du début du XVI[e] siècle (Boisseuil et Chareille 2009).

[64] Notamment pour l'organisation du travail qui était un élément essentiel de la production, cf. Braunstein 2003b.

[65] Sur l'importance d'apprécier à différentes échelles, de temps et d'espace, ces circulations, cf. Hilaire-Pérez 2015.

[66] On connaît encore mal les structures de production anatoliennes.

très vite trouvé, grâce à la densité des réseaux marchands européens, à écouler leur production. En sorte, que déjà avant 1480, le manque d'alun redouté à l'issue de la chute de Constantinople, paraissait un lointain souvenir…

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Sandra de la Torre Gonzalo

Management and governance of the kingdom's finances. Financial literacy as useful knowledge in late-medieval Aragon (1365-1515)[*]

This paper's primary research question is to examine to what extent changes in mechanisms and instruments of financial management proceeding from trading knowledge improved the efficiency of late-medieval polities (van Zanden *et al.* 2012). To do so, we will examine a territorial state experience in medieval Iberia.[1] The Kingdom of Aragon was one of the component realms of the Crown of Aragon, a singular political entity (Barton 2021). In the mid-14th century, a greater level of sophistication in the administration of public finance all over the Crown was accompanied by the birth of supra-local polities. Aragon designed its own autonomous fiscal system which was integrated into the management of the kingdom's finances. When the newly established permanent representative institution of the realm (known as the *Diputación del Reino*) made its first steps, it needed financial accounts to keep track of revenues and to access credit, which led to the refinement of documentary practice and monitoring methods.

This study highlights the agency of accounting-trained individuals who shaped the functioning of financial institutions, using their trading knowledge to improve the efficiency of the latter in a number of ways, from budgeting to tax collecting (Silvestri 2020).[2] The chief sources used here are parliamentary proceedings and the account books produced for financial auditing purposes.[3] Thus, particular attention has been paid to the impact of the increasing prominence of financial numeracy on institutional accountability and governance.

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[*] The research for this paper was supported by a postdoctoral contract granted by *Convocatoria 2019 de contratos postdoctorales de la Universidad de Valladolid* (ref. POSTDOC UVA04) and the funding of *Ayudas de bolsas de viaje para intervenciones en congresos científicos de la Universidad de Valladolid 2022* (ref. AYUDBV-2022-27). It forms part of the results of the research project 'El ejercicio del poder en la Edad Media: espacios, agentes y escrituras (siglos XI-XV)' (ref. HAR2017-84718-P) and the group 'Leon y Castilla en la Alta y Plena Edad Media', led by Carlos Reglero. Additionally, this study is in line with the interests of the Aragonese Government's Reference Research Group CEMA, led by Carlos Laliena (Universidad de Zaragoza).

[1] The characteristics of the creation of a province-wide public debt system are still the subject of debate, but the realms of the Crown of Aragon were among the earliest to adopt it: Haemers 2015.

[2] Literature so far has produced evidence of the emergence at the end of the Middle Ages of new power groups (Dumolyn, 2006) in which merchants succeeded thanks to specific knowledge (Tognetti 2018; Igual 2016).

[3] An exhaustive list of documentary material is offered in the systematic analysis of the institution during the reign of Ferdinand II made by J. Ángel Sesma: Sesma 1977. In 2020, I identified in the collection of the Banco de España the account book for 1436-1437: FEV-SV-M-00218.

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Referee List (DOI 10.36253/fup_referee_list)
FUP Best Practice in Scholarly Publishing (DOI 10.36253/fup_best_practice)

Sandra de la Torre Gonzalo, *Management and governance of the kingdom's finances. Financial literacy as useful knowledge in late-medieval Aragon (1365-1515)*, © Author(s), CC BY 4.0, DOI 10.36253/979-12-215-0092-9.21, in Giampiero Nigro (edited by), *L'economia della conoscenza: innovazione, produttività e crescita economica nei secoli XIII-XVIII / The knowledge economy: innovation, productivity and economic growth, 13th to 18th century*, pp. 352-372, 2023, published by Firenze University Press, ISBN 979-12-215-0092-9, DOI 10.36253/979-12-215-0092-9

1. *Quod omnes tangit*: the birth of territorial taxation in the Kingdom of Aragon

In accordance with the classical legal maxim *quod omnes tangit ab omnibus comprobetur*, the representatives of the king of Aragon's realms were consulted increasingly often at political assemblies called *Cortes*.[4] All of the orders contributed in all the states of the realm, but not with the same criteria. Representatives of nobles, clergy and royal towns constituted separated orders (called *braços* or arms in Catalan and Aragonese languages), of which there were four in the case of Aragon (aristocrats and petty nobility were separated). Frequent discussions occurred regarding the methods for collecting the extraordinary contribution and distributing it between the *braços*. The application of the agreed general taxation was temporary because it was intended to prevent it from becoming permanent. It was also free from intervention by the king, his lieutenant or his officials, with each *braço* having its own treasurer responsible for the collection and management of their corresponding part of the subsidies. These aids were granted voluntarily by the *Cortes*, which meant that the conditions were laid down in an agreement (some were even provided in the form of loans).[5] This arrangement was peculiar to these territories as opposed to the neighbouring Crown of Castile (Ladero 1999). Nevertheless, the monarchs resorted to private credit or appealed directly to the royal towns (de la Torre 2018a; García 2006).

The context of this great transformation (Sánchez, Furió and Sesma 2008) is a long war between the two major Iberian states in the late Middle Ages (Lafuente 2018; Kagay 2016). The king of Aragon's requests during the War of the Two Pedros (1356-1369) were promptly answered due to the urgent defensive needs of the territories (Ferrer 2004). The critical situation at that time discouraged the use of traditional forms of taxation, and the representatives of Aragon, Catalonia and Valencia found an alternative that exploited a new source of fiscal income with little impact on individual economies. The general gathering of *Cortes* in 1362-1363 promoted a common project that sought to guarantee the funding of the major defence expenditures. The representatives of the three territories designed a new customs duty of universal application with no exemptions, which carried the name of *generalidades* (referring to its general scope).

As a consequence, legislation was changed to overcome the traditional division by *braços*. The political role of the commissions of the *Cortes* was strengthened and new representative bodies were fostered: the period 1362-1363 is considered to be the birth of the *diputaciones*, although their formalisation as permanent institutions occurred later. The three (in Aragon, Catalonia and Valencia) shared the central concept of the *General* as a union of interests that brought together all of the inhabitants in each of the three territories, but they differed widely in their attributions and functioning (Sesma 1977; Muñoz 1987; Sánchez de Movellán 2004). Frequent gatherings provoked by the continuing military tension throughout the 1360s-1370s consoli-

[4] The records of the Aragonese meetings have been published recently by the Research Group CEMA (Universidad de Zaragoza) in the series *Acta Curiarum Regni Aragonum* (ACRA).

[5] ACRA V, 46-47 and 98-99.

dated these parliaments' delegations (Lafuente 2021). From 1436, when the institutionalisation of the Aragonese *Diputación* took place, its powers went beyond a merely fiscal and financial body.[6] The deputies had previously assumed a greater political role in the kingdom and the Crown, but it was the reformation accomplished in 1436 which awarded them governmental functions at the highest level.

The economic functions of the *Diputación* in the Kingdom of Aragon were distributed between three management organs, which overlapped in terms of attributions and personnel. Firstly, the leaseholders of the *generalidades*, who had their own staff; secondly, the administrators of the *General*, bearers of mercantile knowledge, were also external to the *Cortes*; and thirdly, the deputies (appointed by the *braços*) who were devoted essentially to resolving issues, arranging the auction of the *generalidades*, authorising payments and auditing the administrator's account books. Initially, the management of the kingdom's finances was a mimetic reproduction of the royal administration and lay in the hands of one *escribano de ración* (paymaster) and one treasurer of the *General*. Both were chosen from among those attending the assemblies and were independent of the treasurers elected by each of the four *braços* (ACRA III, 164 and 192; ACRA IV, 288; ACRA V, 78-79).

The position of administrator distances Aragon particularly from the Kingdom of Valencia, where three deputies (representing the three *braços*) exercised this role through territorial sub-delegates (Muñoz 1987). In Aragon, the administration of the kingdom's finance was handed to an outsider linked to the leasing of the *generalidades* (Sesma 1977). The position involved collecting the amounts pertaining to the leasing of the *generalidades* and the completion of payments ordered by the deputies. During the period of direct management of the *generalidades* (1451-1464), the administrator received a salary and was elected by sortition. The positions of main leaseholder of the *generalidades* and administrator of the *General* were fused into one person from 1465 onwards.

2. The *Diputación* revenues

2.1 A customs duty: the *generalidades*

It was said in the *Cortes* of Barcelona in 1431-1434 that the *generalidades* were the fundament of the *General* (referring to Catalonia), with the *General*'s performance capacity reliant on them and on their expeditious and prompt exaction (Ortí 2011, 120). In Aragon, also, the new general duty became the pillar of a stable tax system with a regular income, and was autonomous (ACRA IV, 291). Its revenues allowed for the design of an economic policy and thus the stabilisation of the *General*'s treasury.

It should be noted that what was conceived as an ambitious common project soon separated the three peninsular estates of the realm (Sesma 2013). Aragon was the first to adapt, in 1364, the same principles of protectionism and interventionism underlying the original proposal to its interests. A network of customs ports on the frontiers of the kingdom taxed exports, initially. Over the following years, the duty

[6] This is coincidental with a reform in the Catalan body adressed in the *Cortes* of 1433: Sánchez de Movellán 2004.

was extended to imports, the fiscal network was expanded to include more customs posts, and the range of products and tariffs (*ad valorem*, 5-10%) changed over time.[7]

The introduction of the new taxation system in Aragon originally met with some resistance (Sesma 2015, 220). The records of the parliaments evince notable tensions between the *braços*. Hence, it was agreed that the establishment of the *generalidades* would be valid during a very limited period and would be under the strict control of the *Cortes*. Nevertheless, the external borders of the Crown were threatened intermittently, leading the *Cortes* to vote, in 1371-1372, to pay the interest on the loan debt taken on by the kingdom (the *General*) using revenue from the customs duties. The collection of such customs duties was to be extended on a monthly basis until the total amortisation of the debt had been achieved (ACRA III, 382). In 1376, the total amount granted to the crown was not distributed between the *braços* for the first time (ACRA IV, 75, 151-153 and 283-284).

Indeed, the *generalidades* were allocated according to a fairly predictable economic pattern. Having an income that was stable and predictable prevented the kingdom from being charged excessive interest. Furthermore, the lease of the *generalidades* assured a fixed amount that was paid promptly to the kingdom's treasury.[8] Unfortunately, only during the period of direct management of the customs duties did the administrator of the *General* record the tax revenues and not merely the price of the lease, which varied according to the custom's tariffs and was often affected by the threat of war.[9]

The *Cortes* (or very rarely the deputies) discussed the contract terms of every new lease of the *generalidades* and awarded the lease by means of an auction, the details of which were announced publicly, in advance, in the main surrounding economic centres. The lease term lacked regularity until the second half of the 15th century, when it adopted a three-year periodicity, coinciding with the deputies' cycles, as had been implemented in Catalonia and Valencia.[10] One of Aragon's singularities is the fact that the collection of customs duties (including the selection of personnel, payment of management costs, etc.) depended on the leaseholder of the *generalidades*. The deputies of the *General* were mainly responsible for ensuring the free collection of the tax and for prosecuting instances of fraud.

[7] The main changes took place in the years 1364, 1376, 1414 and 1436: ACRA II, 413; IV, 96-102; VIII, 413-414; IX, 191; *ibid.*, 512-513.

[8] The instalments for the concession of a loan to the king in 1381 were scheduled by the Aragonese representatives according to the payments made by the leaseholders of the *generalidades*: ACRA V, 98-99.

[9] J. Á. Sesma estimates that the customs tax revenues could have reached more than £40 000 in 1446-1449: Sesma, 2020. From the direct management period, the surviving account books correspond to the fiscal years 1450-1451, 1453-1454, 1456-1457, 1457-1458 and 1460-1461: Sesma 2013, 129. Although the total amount is not altered significantly, the detail of each customs post reveals the volatility of this tax: Sesma 2013, 150-55.

[10] The *generalidades* were leased yearly in Catalonia until 1390: Ortí 2011, 122.

2.2 Other tax revenues

The *generalidades* constituted a common project with a common funding pot. Despite this, financial emergencies required an increase in the tax burden (Lafuente 2019) and the *Cortes* reflected a clash of interests when trying to modulate the level of fiscal pressure. The representatives of the kingdom continued to approve the traditional methods of collection and to share the amount between the *braços*.[11]

Tab. 1. **Funding of extraordinary expenditure by the *General* of Aragon agreed in Cortes (in Jaca pounds)**[12]

Year	Subsidy	Troops	*Fogaje*	*Sisa*	Annuities
1376	78 000				
1381	58 500				
1383-1384	-				
1388-1389	-				
1396		19 212			
1398	75 000	50 000	x		22 212
1404			x		
1412	27 500				x
1423	25 000				20 000
1427-1428	62 040				26 000
1436	112 500				127 500
1441	55 000				82 500
1442		x		x	
1446-1448					9 000
1450					25 000
1451	[60 000]				
1452		36 000		x	28 000
1453		12 000			

A *sisa* was a tax levied on consumption and market selling (mainly on staple food products). It was the preferred method of collection by the royal *braço*. From the end of the 14th century, *sisas* were banned under penalty of excommunication, but this did not prevent their reintroduction in 1442 for the defence of the kingdom (ACRA X, 472-76). Likewise, the clergy and noble *braços* preferred the *fogaje* (a hearth tax), which allowed them to benefit from their particular privileges. The tax collection was a very slow process and a source of conflict. Each *braço* commissioned a series of

[11] Different duties on consumption and trade (*vectigal* and *gabela*) which were separate from the *generalidades* were established in the first stage of the *Diputación*. Notwithstanding, the deputies feared the impact that an excessive increase in sales tax could have on trade and manufacturing production, and these formulas were soon abandoned. In this regard, in Catalonia, the leasing contract could be terminated in case of levying a *vectigal*: Sánchez de Movellán 2004, 308.

[12] Sesma 2015. Data is collected from the parliamentary records. Currency: 1 pound (*libra*) = 20 shillings (*sueldos*) = 240 pence (*dineros*). For ease of reading, conversions to Jaca pounds are given, but it should be borne in mind that these exchanges depended on the currency market. The Aragonese gold florin was used frequently as a currency of account valued at 10 shillings per florin.

collectors who were usually financers who advanced the money, managed the collection process and received the interests generated. In 1484, the *General* established a levying system that merged *sisas* and *fogajes*, and was managed by the administrator of the kingdom (Sesma 1977, 140-48).

2.3 Credit and the emergence of consolidated debt

Violarios (lifetime annuities) and *censales* (redeemable annuities) offered much lower rates of interest than traditional forms of credit (García 2002). The widespread use of these credit instruments caused interest rates to plunge to 5% at the end of the 15th century.[13] Additionally, the consolidation of public debt eventually enabled the kingdom to get rid of the royal interference exerted by the financers of the crown.[14]

Tab. 2. **Interest rates of annuities issued by the *General* of Aragon (modal value in percentage)**[15]

1376	1391 - 1392	1393	1394	1396 - 1397	1400	1401 - 1416	1428/ 1436	1442/ 1451	1454/ 1461/ 1481	1495	1500
10	9.09	8.33	10	9.09	7.69	6.67	6.67	6.25	6.67	5.88	5

The first issues of annuities by the *General* were virtually coincidental in Aragon, Catalonia and Valencia (Sánchez 2009; Muñoz 1987). In 1376, the Aragonese assembly authorised the first issue of *censales* at an interest rate of 10%, although it was not opened to investors (ACRA IV, 108; Sesma 2015, 222). The debt was paid for with the income of the *generalidades* tax and guaranteed with the assets (and persons) of each and every one of the inhabitants of the kingdom. In these early years, the public debt system was not taken advantage of in all of its possibilities and the deputies tried to cancel the debt as soon as possible.

Four meetings of *Cortes* took place prior to the next order issuing annuities, in 1398. This state of affairs appears to contradict the claim being made at that time that the *General* was owed a lot in annuities (ACRA VI, 249). In the light of new data available, we know that new annuities were issued from at least 1391 onwards (de la Torre 2022).[16] The downward trend appreciable at this stage (Tab. 2) is marked by wild fluctuations produced by new royal demands and political instability at that time (de la Torre 2018b). The plan of getting credit from purchasers of new annuities in

[13] The reasons behind the decrease of interest rates in many different European territories are still subject to debate: Stasavage 2011.

[14] ACRA II, 418; ACRA III, 45-48, 160-163, 185-187, 193 and 199.

[15] Sources: Archivo de la Diputación de Zaragoza (ADZ), ms. 681-2, ms. 681-3 and ms. 35; Sesma 2015; Sesma 1977.

[16] The issues are recorded in an inventory of the documents kept in the *Diputación*'s archive made presumably by the end of the 16th century: ADZ, ms. 5.

order to release the kingdom from its debt worked, and the interest rate was drastically reduced: bonds were last sold at 10% in 1398 and the maximum rate in 1400 was 7.69%.[17]

Nonetheless, due to the financial hardship that the *General* was experiencing, the *Cortes* forbade new issues of public debt in 1404 (Sesma 2015, 227). The following years are characterised by small issues of new bonds and stable interest rates. The deputies sought to generate investment confidence and offered new guarantees (ACRA VIII, 342-345). Until 1454, all assemblies ordered the issue of public debt (the average sum was £24 000) with few exceptions (Tab. 1). Good progress had been made by this point: in 1427-1428, the *Cortes* restricted the issue of new annuities to the Aragonese market and established a maximum interest rate of 6.67% (ACRA IX, 8; 273). Bonds were sold easily and the kingdom overcame the difficulties of the 1440s (Sesma 2015, 234). However, it is evident that there was a turnaround in the following decade (Tab. 2): in 1454 the deputies offered an interest rate of 6.67%. Previously, the *General* had sold a batch of annuities to the administrators directly instead of commissioning them for that purpose (ACRA XI, 793-794). It was not until the bailout of 1488 that the interest rate resumed its downward trend.[18]

3. The *Diputación* expenses

Salaries and management costs remained low, similarly to what happened in Catalonia and Valencia. The bureaucratisation of the *Diputación* in 1460-1470 increased the budget allocated for salaries and management costs (Sesma 1979, 198-199). On average, the administrator paid £3 500 in 1479-1515, representing 7.9% of revenues (Sesma 1977, 149-166).

The weakness of the described system was that the debt accumulated easily and thus the threshold of the kingdom's spending escalated. Consequently, an increase in tax income was consumed by the payment of the interest. Thus, public debt management became the financial focus of the *General* of Aragon. The first documented decision in this regard is an order given in 1394 by the deputies to use part of the price of the *generalidades* to reduce the *General*'s debt (de la Torre 2018a, 84-85). Four years later, the *Cortes* approved the introduction of extraordinary duties for the consolidation of public finances. The debt reduction plan continued in 1404 and sought to reduce the amount devoted to interest payments by redeeming the debt bonds sold at higher interest rates, or at least renegotiating a decrease in interest rates (ACRA VIII, 342-45).

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[17] ADZ, ms. 681-3, f. 43; *ibid.*, 46v-48.

[18] Catalan deputies were also forced to offer notably higher interest rates during the Civil War: Miquel 2022, 123 and 126.

Tab. 3. **Evolution of the *General*'s annuities (in Jaca pounds)**[19]

Financial Year	No. of annuities	Annuity payments
1417-1418	343	13 379
1420-1421	267	9 443
1428-1429	198	7 423
1432-1433	209	8 397
1436-1437	141	5 394
1437-1438	345	17 317
1442-1443	412	17 208
1447-1448	432	17 585
1450-1451	459	17 735
1453-1454	550	21 165
1456-1457	593	21 929
1460-1461	597	21 385
1465-1466	726	30 260
1467-1468	741	29 853
1468-1469	752	29 110
1472-1473	805	28 495
1474-1475	811	28 406
1475-1476	807	27 853
1481-1482	858	26 911
1485-1486	870	26 810
1486-1487	887	26 596
1487-1488	899	26 686
1488-1489	913	26 783
1489-1490	922	26 676
1490-1491	924	27 332
1494-1495	801	21 063
1495-1496	976	15 749
1496-1497	768	20 258
1500-1501	735	19 159
1502-1503	748	18 838
1513-1514	761	24 504
1514-1515	762	24 448

The administrator started a campaign of reductions agreed with the holders of *censales* and forced repurchases during this period, although overall figures are not

[19] Pub. Sesma 1979, 202; Sesma 1977, 133 and appendix II. Data is collected from the accounting books of the *General*'s administration. I have included data for 1436-1437 from the Biblioteca del Banco de España, FEV-SV-M-00218. Despite the time that has elapsed, Hamilton (1936, 81-115) is a solid reference for approximating the impact of inflation on the Aragonese public debt. After an abrupt price spike in the second half of the 14th century, an irregular rise of prices in 1401-1444 was accompanied by monetary inflation in the kingdom (*ibid.,* 189-204). Nonetheless, this was followed by a pronounced decline and a period of falling prices in Aragon (*ibid.*, 195). Hamilton argues that the debasement of the coinage was responsible for a more stable price level in the second half of the 15th century (*ibid.*, 106). As for wages, they moved more slowly than prices from the second quarter of the 15th century (*ibid.*, 113).

available until 1417 (de la Torre 2022; Sesma 1979, 182). The budget assigned to annuity payments and the number of bonds dropped in ten years. This operation of debt reduction also affected the average interest rate to the extent that all the amortised annuities in 1421-1422 were at 6.25%.[20] The leasing contract of the *generalidades*, in 1428, included the commitment to redeem £50 000 over six years (Sesma 1979, 184-185; ACRA X, 808).[21] This policy exclusively affected annuities paid in Barcelona currency, some of which were lowered by 10-15% (Sesma 1979, 187). The Aragonese deputies achieved a reduction in extra costs and, most importantly, in the pressure exerted by foreign investors.

In the 1440s, the annuities paid in Barcelona currency increased by 15% and the return of capital was 180% higher than ten years earlier (Sesma 1979, 190). With the outbreak of the Catalan Civil War (1462-1472), John II banned the payment of interest to Catalan investors (Sesma 1979, 199-200). Despite the alleviation of expenses resulting from the postponement of a considerable number of annuity payments, pressure on the *Diputación* in 1480-1490 led to protectionist measures being taken. In 1483-1485 the deputies authorised the *General*'s administrator to delay the interest payments for the annuities paid to Aragonese investors by 4 months, and the ones paid in Catalonia by 7 months.[22] Catalan investors, who received lower interest rates, had to be paid in Zaragoza according to the exchange rate established in the Aragonese capital, which clearly favoured the local currency over the Barcelonese. In 1490, Ferdinand II compelled the deputies to reverse the discriminatory measures taken.

The bailout introduced by the king in 1488 included a forced purchase of annuities at 5% made by the Aragonese officers of the royal court (Sesma 2015, 239-240). Equally, royal mediation resolved the issue of Catalan investors being owed annuities from many previous years. Additionally, the *General* offered its investors a reduction from 6.67-6.25% to 5%, or else the amortisation of the annuity. In the aftermath, there remained what Sesma identifies as a small group of Catalan investors who had significant business dealings with the kingdom (Sesma 1977, 134-137).

4. The balance

The most commonly used strategy for ensuring a balance in the *General*'s accounts was to keep income high and to borrow with this endorsement.[23] Availability of liquidity allowed the kingdom to meet the royal petitions and progressively develop the *Diputación*'s own activity.

A decisive reform for the Aragonese treasury took place at the beginning of the 15th century, justified by the debts that beset it (Sesma 1979, 179-82). The merchant

[20] ADZ, ms. 13, ff. 50v-64. Administrators did not register the capital or interest rates (*razón*) on the list of paid annuities in the account books, but they did when it came to debt amortisations.

[21] As a short-term measure, £10 000 that arose from the issue of annuities in 1450 was reserved to make the interest payments on the debt (ACRA X, 977).

[22] Hereafter, the administrator negotiated a new extension to 6 and 10 months respectively, in exchange for covering an existing deficit of £14 000: Sesma 1977, 151-152.

[23] Incidentally, some efforts were made to work within the budget, using efficiency measures to keep expenses under control.

Ramon de Casaldáguila had been advancing cash to reverse an untenable situation of excessive expenditures and constrained incomes, which had been aggravated during the struggles of the Interregnum (1410-1412).[24] Budgets were remodelled and the *Cortes* extended the customs duty to more products. In 1428, the deputies repeated the strategy of raising the income of the Aragonese treasury by increasing the tariffs of the *generalidades*, and established more control over the management of the kingdom's treasury (ACRA IX, 191-198).

Tab. 4. **Balance of the *General* (in Jaca pounds)**[25]

Year	Income	Outcome	Balance
1410	23 892		
1411	16 934		
1412	17 069		- 15 000
1413	17 699		
1416-1417			13 154
1417-1418	52 665	47 633	5 032
1419-1420			5 949
1420-1421	46 949	36 608	10 341
1428-1429	69 314	69 314	
1432-1433	31 741	31 738	3
1435-1436	20 000	11 058	8 942
1436-1437	30 000		9 662
1437-1438	39 662	25 344	14 318
1439-1440			12 796
1440-1441	42 916		
1441-1442			30 855
1442-1443	60 905		
1446-1447			14 528
1447-1448	57 528	40 552	16 976
1450-1451	34 446	24 628	9 823
1452-1453			15 296
1453-1454	46 076	33 775	12 301
1455-1456			42 951
1456-1457	74 094	48 140	25 954
1459-1460			38 360
1460-1461	148 743		
1465-1466	27 100	26 799	301
1466-1467			240
1467-1468	28 676	28 818	- 142
1468-1469	30 650	30 228	422
1471-1472			1 519
1472-1473	34 708	31 934	2 774
1474-1475	32 152	32 616	- 464
1475-1476	32 189	32 466	- 276
1480-1481	(20 050)	(31 115)	- 3 066

[24] Sesma 2011. Casaldáguila had taken responsibility, in 1404, for the collecting of the *fogaje* implemented to inject funds into the *General*, which had not yet been completed: de la Torre 2018a, 325-26.

[25] Pub. Sesma 1977, 172; 1979, 201. Figures in brackets are estimates based on fragmentary data.

1481-1482	28 050	31 389	-	3 339
1483-1484	(29 550)	(34 537)	-	4 988
1484-1485	(29 550)	36 965	-	7 415
1485-1486	29 586	27 326		2 259
1486-1487	29 309	39 375	-	10 065
1487-1488	27 050	42 642	-	15 592
1488-1489	27 050	49 051	-	22 001
1489-1490	26 575	54 210	-	27 635
1490-1491	51 809	58 447	-	6 619
1491-1492	(26 550)	(39 061)	-	12 511
1492-1493	(30 050)	(44 870)	-	14 820
1493-1494	(30 050)	(46 284)	-	16 234
1494-1495	30 050	39 990	-	9 940
1495-1496	30 050	36 091	-	6 061
1496-1497	30 050	33 731	-	3 681
1497-1498	(30 050)	(33 131)	-	3 082
1498-1499	(30 050)	(37 040)	-	3 990
1499-1500	(30 050)	(33 651)	-	581
1500-1501	33 056	27 091		5 965
1501-1502				(+)
1502-1503	35 050	36 776	-	1 726
1503-1504				(+)
1504-1505			-	2 257
1505-1506				4 048
1506-1507				(+)
1507-1508	(37 250)	(38 277)	-	1 029
1508-1509				(+)
1509-1510	(37 250)	(31 052)		6 199
1510-1511				(+)
1511-1512	(37 850)	(30 084)		7 767
1512-1513	(37 850)	(47 486)	-	9 636
1513-1514	37 241	42 540	-	5 297
1514-1515	36 322	37 926	-	1 604

Meanwhile, the intense activity of the deputies translated into an increase in administrative costs and officers' salaries, which consumed the surplus from the previous financial years on an annual basis.[26] From 1445 onwards balances remained positive due to new issues of annuities, and the fact that the administrator included, in 1453, for the first time, the sums levied by the *sisa* (Sesma 1979, 196). Undoubtedly, the Catalan Civil War deeply affected Aragon, and the fiscal year 1464-1465 was the first to have a shortfall since the reforms were enacted in 1414 (Sesma 1979, 197).[27] At this point (1465), the decision taken in the *Cortes* of 1446-1450 for the generalidades to be managed directly by the deputies was reversed. The leasing of the *generalidades* was reintroduced, which had the benefit of having the financial support of

[26] In 1451-1453 the *Cortes* resorted to using all of the funds available in the *General* to pay the defensive troops, and the experts consulted warned that the kingdom's funds were exhausted and that the collectors would be uncapable of raising extra cash from the population: ACRA XI, 631.

[27] The *General*'s administration books for the period 1461-1464 have not survived up to the present.

the *General*'s administrator, who would advance money to balance the accounts. From 1465 to 1488, the verifiable balance between expenditure and revenue is artificial given the enormous number of unpaid annuities (Sesma 1977, 202).

The establishment of the *Inquisition* in the kingdom in 1488 led to the *converso* capital flight, which was significant because such capital had been an important support for the kingdom's trading activity (Sesma 1977, 169-73). This added up to a lack of Catalan investors and market saturation within Aragon. *Sisas* and *fogajes* were simultaneously reintroduced in an attempt to balance the steady increase of the deficit due to higher ordinary expenditures and a drop-in income from the lease of the *generalidades* (conflicts translated into low prices offered at auctions). The *General*'s administrator covered a growing amount of shortfall to the extent that the advance made to the kingdom's finance was higher than the total income of the financial year and the expected revenues for the following years. A way to address this shortfall was to default on annuity payments in the last months of the year so that the money could be used to pay the past interest owed (Sesma 1977, 367-93). Thus, the kingdom avoided having old debts, which could lead to legal claims and reprisals.

Eventually, the *General* of Aragon escaped bankruptcy and the effects of the bailout approved in the *Cortes* of 1488 gradually became visible (Sesma 1977, 237-43). The plan restrained spending and drove up the price of the leasing of the customs duties. The recovery was tangible in 1493 when interest rates of annuities were low and income increased, to the extent that in 1499 the shortfall was the smallest of the previous two decades (Tab. 4). Thus, the *General*'s solvency margin did not fall below the desired level despite the disbursement of the missed annuity payments made in Catalonia. Nonetheless, the conquest of Iberian Navarre (1512-1524) did erode the effectiveness of the measures. Once again, a military conflict brought an increase in extraordinary expenditure and weakened revenues from the customs duties, thus cancelling the trend of positive balances that had started in 1505.

5. 'For the good of the kingdom': political scrutiny and mercantile action

The management of the Kingdom of Aragon's finances merged public good and private interests. Since the beginning of the 15th century, power was concentrated in the hands of the *General*'s administrator (Viu 2022). Initially, that responsibility fell to merchants very close to the royal court.[28] They were among the royal family's moneylenders and were also very knowledgeable about the territory.[29] The position was tied to the leaseholders of the *generalidades*, the latter being leased as a whole, unlike in Valencia and Catalonia. Already, in 1376, there is evidence of a system by which

[28] Ramón de Màrgens, a Barcelonese merchant settled in Zaragoza and the first leaseholder of the *generalidades*, was a brother of Pere, assistant treasurer to Peter IV. In 1381, the infante Martin (who would succeed his brother John I to the throne) was initially involved in the lease with the merchant Juan Donsancho: Archivo de la Corona de Aragón, reg. 2071, f. 92v (Tortosa, 1383, 11 January). I owe this reference to the kindness of Carlos Laliena.

[29] Juan Donsancho collected, in 1375, the amounts of the *fogaje* corresponding to the clergy: ACRA III, 573-589.

the *generalidades* were leased by a share company.[30] The leasing company's shareholders were expected to reap benefits and the administrators made every effort to receive compensation for losses and to attract taxpayers (Viu 2021).[31] This sort of compensation authorised by the deputies was less frequent after Juan de Mur left the *General*'s administration (Sesma 1977, 167-68).

As early as 1381, the *Cortes* started an enquiry into the management of the leaseholders. Under the accounts clearance procedure, the amounts due to the *General* were claimed from their heirs.[32] Equally, the participants at the assembly denounced some payments made by the *General* which were ordered by the king, condemning this royal intrusion into their autonomy (Sesma 2015, 224). As shown above, deputies and participants at the *Cortes* made decisions concerning fiscal policies and the amount and composition of the public debt. The kingdom's creditworthiness was their responsibility and it largely depended on the punctual payment of debt interests.[33] Parliamentary proceedings include frequent allusions to investor confidence, which was dependent on the kingdom's financial solvency and the debt it had accumulated. This was particularly apparent during the political instability of 1396-1398, when the Aragonese faced problems selling new annuities because the parliaments had not established the exact amount they planned to raise through the issuing of public debt. Presumably, investors distrusted an institution that, lacking control, could borrow beyond its capacity (de la Torre 2018b). The Aragonese representatives were particularly worried about foreign investors: amortisation of annuities sold in Catalonia was ordered repeatedly and some issues were limited to the domestic market.[34] The price of the lease of the *generalidades* was of constant concern to the deputies.[35] At the time of negotiating the terms and duration of the contracts, it was not unusual for some refinements to be made to the offered securities for the leaseholder and the kingdom.[36]

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30 ACRA IV, 114-115. The system imitated the one used by the shipping companies. It was adapted in Aragon for the management of financial businesses: de la Torre 2018a, 156 and 169-74.

31 We know that, after a term of losses in 1423, the leasing company headed by Ramon de Casaldáguila registered a term of profits in 1426, which compensated the prior situation by an overall net gain of 15%: de la Torre 2018a, 174.

32 ACRA V, 64, 72, 81, 94. This took place in the context of a widespread phenomenon of public accountability in the Crown of Aragon at the end of the 14th century: Lafuente 2016.

33 In 1452, the *Cortes* authorised the administrators to only make the payment of arrears and the annuity payments that had to be accomplished in the current month before delivering the money to the deputies so they could pay the troops their salaries: ACRA XI, 157-58. The Aragonese representatives stated that by doing so they sought to preserve the creditworthiness of the kingdom.

34 In 1428, the deputies gave the *General*'s administrators a detailed list of annuities to be cancelled in Catalonia: AHPNZ, Antón de Salavert, 3382 (1428), no foliation. I owe this reference to my colleague Maria Viu. In 1452, the *General* was in need of cash to pay the defensive troops, but the deputies preferred asking for a loan to selling more bonds to Catalan investors: ACRA XI, 175-76.

35 Sesma 1977, 115-18. The auction was announced widely and the deputies insisted, in 1417, on the process being publicised openly so that the price could be higher, they asserted: ADPZ, ms. 773-15, ms. 750-9 and ms. 746-46.

36 The *General* of Catalonia in 1413 contemplated the possibility of commissioning the *generalidades* for a lower price in the event of not finding a leasee (Sánchez de Movellán 2004, 311-12), a measure that was never necessary for Aragon.

Tab. 5. ***General*'s administrators**[37]

Contract term	**Leaseholders / Administrators**	**Price of the leasing (pounds per year)**
1364-1365	Ramon de Màrgens	2 500
1366	Ramon de Màrgens	3 240
1367-1371	Simón Mayor - Vidal de la Caballería	9 000
1376-1384	Blasco de Azlor, knight - Juan Donsancho	11 000
1394-1398*	Beltrán de Coscó	19 000
1399-1404*	Arnalt Noguer - Pedro Tudela - Samuel Najarí	23 000
1404-1413	Ramón de Casaldáguila	no data
1414-1417	Ramón de Casaldáguila	35 000
1417-1420*	Ramón de Casaldáguila	35 600
1420-1421*	Ramón de Casaldáguila - Jordi de Camprodon	41 000
1422-1423	Ramón de Casaldáguila - Jordi de Camprodon	22 050
1423-1428	Ramón de Casaldáguila - Jordi de Camprodon	20 000
1428-1436	Ramón de Casaldáguila - Juan de Mur	28 000
1436-1443	Juan de Mur	30 000
1444-1450*	Juan de Mur - Pere Vedrier	34 000
1451-1464	Miguel Homedes – Domingo Aznar	Direct management
1465-1467	Fernando de Bolea	27 100
1468-1470	Juan de Lobera - Francisco del Río	30 600
1471-1473	Miguel López-Jaime Sánchez-Ramón de Casteldasens-Francisco Climent	33 100
1474-1476	Pedro Ortiz	32 100
1477-1479	Pedro de la Caballería	30 200
1480-1482	Juan de Pero Sánchez	28 000
1483-1485	Domingo Aznar	29 500
1486-1488	Pedro Torrero	27 000
1489-1491	Pedro Torrero	26 500
1492-1494	Pedro Torrero	30 000
1495-1497	Pedro Torrero	30 000
1498-1500	Miguel Torrero	33 000
1501-1503	Miguel Torrero	35 000
1504-1506	Felipe de Ortal	36 100
1507-1509	Jaime Cariñena	37 200
1510-1512	Juan Torrero	37 800
1513-1515	Juan Torrero	36 200

One of the main functions of the leaseholders of the *generalidades* in the early years was to provide credit secured against the income from the customs duties. And it was precisely this skill to obtain money more cheaply that the potential leaseholders of the *generalidades* highlighted in 1376 (ACRA IV, 128-29). In 1414, following several years when the *General*'s administrator advanced considerable amounts of money (ACRA VIII, 415-416), the reforms introduced for the kingdom's finances included new guarantees for the leaseholders. This allowed Ramón de Casaldáguila to remain

[37] De la Torre 2018a, 331; Sesma 1979; Sesma 1977, 123. * Contract not granted at *Cortes* prior to the reform carried out in 1465.

in office until his death in 1428.[38] Furthermore, the following *General*'s administrators were praised by their deputies for their outstanding performance.[39]

The *General*'s administrators presented their arguments to the deputies in the yearly accounts (Viu 2022). The structure of the account books used by the *General*'s administration did not differ essentially from 1417 to 1515: income (payments of the leasing of the *generalidades* and remaining balance from the previous year), expenses (salaries, detailed annuity payments and any other ordinary or extraordinary costs) and balance. They were instruments which were inspected by the auditors and updated by specialised scribes, who incorporated novelties that arose after the monitoring of accounts (such as back payments). The *General*'s administrator kept economic documentation (proof of payments, payment orders, etc.) and was helped by a handful of auxiliary instruments, such as a general journal (recording debited and credited entries) or a journal dedicated to recording courier costs. Given the importance of the public debt, the *Diputación*'s notaries wrote a census (*padrón*) of the annuities to keep up with ownership changes and further amendments to the *General*'s consolidated debt.[40]

Aragon's finances faced cyclical financial problems. Deep reforms and even two bailouts over the course of the 15th century helped to overcome several financial crises, which might otherwise have led to the kingdom's bankruptcy.[41] Extraordinary formulas were approved in 1398 to extend the income of the Aragonese treasury, but already, in 1400, the deputies were appealing for financial recovery measures that were finally launched in 1404 (Sesma 2015, 226-29). This bailout avoided the *General* collapsing. The task fell to the merchant Ramon de Casaldáguila, who went on to be put in charge of the institution's finances, combining the duties of the *General*'s treasurer with those of the administrator permanently (de la Torre 2018a, 305-307). He worked to reduce the Aragonese treasury's level of debt, thus increasing confidence in the institution, which translated into an interest rate five per cent lower than five years earlier (Tab. 2).

The administrative transformation of the *General*, in 1414, came at the beginning of the Castilian Trastámara dynasty's rule over the Crown of Aragon. This regulation sought to introduce rationalisation in expenditure and income.[42] The deputies established an order regarding payments: the administrator was compelled to prioritise annuity payments and to use any surplus to amortise the annuities with higher interest

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[38] his associate, the merchant squire juan de mur, succeeded him and held the position for 22 years.

[39] Juan de Mur received a generous incentive in 1441: £3 000 for the selling of annuities and £1 500 for the reduction of the debt: ACRA X, 93-95 and 115-120.

[40] This systematic monitoring registry of annuity payments is earlier than previously thought (Sesma 1977, 127). The *Diputación*'s archive has preserved a volume containing annuities issued from 1436 to 1453, whose changes over time are recorded until the late 1470s: DPZ, ms. 35.

[41] Bankruptcies of towns were not infrequent in Aragon and Calatonia in the 15th century: Ortí and Verdés 2016; de la Torre 2018a.

[42] Cost control was addressed by halving the number of deputies (from 8 to 4) and reducing the salaries, travel and daily subsistence allowance, and other expenses (Sesma 1979, 179-182).

rates. The payment of salaries, debts to the administrator and extraordinary costs (up to a limit of 300 florins per year) had to adhere to this specific order.[43]

The institutionalisation of the *Diputación* took place in 1436 (ACRA IX, 536-39, 577-80). Just a decade later, following a recent structural reform in 1446, a new era began with the suspension of the leasing system in 1450-1464 (Sesma 2013, 402-12). Following a proposal from the king, the deputies decided to take control of the *General*'s administration and the collecting of the *generalidades*, which were also restructured. A revenues scheme was introduced, giving more power to the deputies, who were responsible for delivering the cash to the administrators for the payments (ACRA X, 970-971). The last reform of the medieval era took place in 1488, when the kingdom was effectively bankrupt and needed a cash injection (Sesma 1977, 179-243).

6. Final remarks

The medieval Crown of Aragon provides a revealing case study in which institutions do not simply develop in response to the needs of their rulers. Rather than an institutional initiative emanating from the central power, institutions develop as a result of the agency of regional power groups. In the Kingdom of Aragon, the intervention of mercantile elites contributed to the shaping the management technique of the *General*. Signs of the impact of the administrator's actions are an increase in spare capacity, the fact that investors were being attracted successfully, and the stimulation of exchanges. Increased efficiency in public administration promoted economic growth via, on the one hand, a decline in fiscal pressure and, on the other, a diminution of risks for investors and traders (Laliena 2016). Notwithstanding, the path was by no means linear. The trend of positive balances that followed the introduction of reforms was broken by cycles of excessive expenditures and wars, which severely affected Aragon's financial situation, while its representatives tested different remedies.

The series of reforms implemented in the *Diputación* led to the development of efficient and innovative practices in the management of the kingdom's finances. Behind them was a spirit of rationalisation that resulted in the involvement of merchants in public administration. Administrators were recruited from the mercantile elite. These businesspeople used their own resources and networks to cover deficits, advance the payment of subsidies and access credit. However, this created a relationship of dependence by the *General* on such businesspeople, who tended to monopolise the position of administrator. As this study has shown, prescriptive information and rigorous accounting records facilitated credit access by projecting an image of creditworthiness to prospective investors. The production of yearly financial accounts helped with verification based on periodic audits, which were expected to ensure good governance.

The individuals who were at the highest levels of power in Aragon understood the importance of keeping records of an economic nature, primarily to exploit the fiscal resources managed by the *General* more efficiently, maximising tax revenues.

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[43] Already, in 1427-1428, the *Cortes* agreed (with the royal *braço* voting against) to raise the limit to a maximum of 500 florins: ACRA IX, 273.

Exemplary management of the public asset was understood as a sign of good governance of the *res publica*. Taxpayers demanded rigorous control of the *General*'s treasury in response to onerous financial demands. Consequently, Aragonese deputies relied on the financial expertise of well-known merchants and their trained personnel. At the same time, they nonetheless exploited the auditing process to assert their authority over the *General*'s administrators.

The emergence of supra-local institutions affected the dialogue of power within the Crown of Aragon, and the need for an efficient tax collection and debt management stimulated both a turnaround in the system of government and a change in relations with the crown (Tracy 1985). Public authorities were aware that their capabilities were based on effective control of their finances (Béguin and Murphy 2017).

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Richard W. Unger

Ships, shipping, technological change and global economic growth, 1400-1800

1. General purpose technologies

Not all technical changes are created equal. Some have greater impact on the economy than others. Some have more influence on the pace, character and extent of other technical changes. Some, though very few, have shaped entire periods in history of not just the economy but the shape and character of society, politics and thought even globally. Paolo Malanima, Paul Warde and Astrid Kander, in their 2013 book *Power to the people: energy in Europe over the last five centuries,* talk about technical blocks, that is a group of innovations which defined long periods in the historical sources and uses of energy. Coal, steam and iron was a development block of the First Industrial Revolution. The internal combustion engine and petroleum formed a block in the late nineteenth century and electricity formed another in the twentieth (Kander, Malanima and Warde 2013, 159-60; 287-88; 303-05). Within each of those blocks they isolate what they call macro innovations which created the blocks dominated by the use of specific sets of energy carriers, Joel Mokyr, in his economic history of technology *Lever of Riches,* also identifies a small number of significant macroinventions (Mokyr 1990, 24-25).

The identification of certain innovations that had extensive and lasting effects on productivity and, therefore, economic growth, at least in English, may well have started with Francis Bacon in his *Novum Organum* of 1620. The context was his programme for thinking about knowledge, how it could and should be created as part of a genuine and rigorous reformation of the study of natural history which he called the *The Great Instauration.* His work encapsulated an interest in and a growing enthusiasm for technology which concentrated on the virtues of advances. In praise of technical change, he talked of:

> [...]the force, effect, and consequences of inventions, which are nowhere more conspicuous than in those three which were unknown to the ancients; namely, printing, gunpowder, and the compass. For these three have changed the appearance and state of the whole world. No empire, sect, or star, appears to have exercised a greater power and influence on human affairs than these mechanical discoveries (Bacon 2014 [1620], 105).

The compass he used as a symbol of a complex of innovations in navigation, ship design and shipping.

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Referee List (DOI 10.36253/fup_referee_list)
FUP Best Practice in Scholarly Publishing (DOI 10.36253/fup_best_practice)

Richard W. Unger, *Ships, shipping, technological change and global economic growth, 1400-1800*, © Author(s), CC BY 4.0, DOI 10.36253/979-12-215-0092-9.22, in Giampiero Nigro (edited by), *L'economia della conoscenza: innovazione, produttività e crescita economica nei secoli XIII-XVIII / The knowledge economy: innovation, productivity and economic growth,13th to 18th century*, pp. 373-393, 2023, published by Firenze University Press, ISBN 979-12-215-0092-9, DOI 10.36253/979-12-215-0092-9

In the same spirit and part of an effort to formalize thinking about such macro inventions Dick Lipsey and Kenneth Carlaw discuss what they call «General Purpose Technologies». They followed Timothy Trajtenberg and Manuel Bresnahan who coined the term, discussing the concept in a 1995 article, and Elhanan Helpman who edited a 1998 volume that explored the effects of GPTs on economic growth (Lipsey, Carlaw and Bekar 2005: Carlaw and Lipsey 2006: Bresnahan and Trajtenberg 1995: Helpman 1998). Lipsey and Carlaw try to offer an abstract model that describes how GPTs work and what their findings might imply for research and development expenditure (Carlaw and Lipsey 2006; Lipsey, Carlaw and Bekar 2005, 371). They define the GPT as:

> A single technology, recognizable as such over its whole lifetime, that initially has much scope for improvement and eventually comes to be widely used, to have many uses, and to have many spillover effects (Lipsey, Carlaw and Bekar 2005, 98).

The examples they offer include recognizable technologies like the automobile, the railroad and electricity. The frequency of appearance of GPTs has been increasing over time. While the nineteenth and, even more, the twentieth centuries offer a number, the period from the thirteenth to the eighteenth century offers few cases. The only two they find which qualify are printing and the three-masted sailing ship (Lipsey, Carlaw, Becker, 168-75; Mokyr 1990, 68). The latter, a product of a complex of advances in shipbuilding, qualified as a GPT because it continued to have widespread effects and had extensive spillovers and encouraged further endogenous change in newly emerging practices and improvements or adaptations of existing practices. GPTs offer opportunities for the greater use of other technologies and can even force changes in those interrelated methods of production. They also create new fields for profitable investment in varied technologies, possibly even in different fields entirely. The impact of the GPT can continue, in some cases over centuries (Lipsey, Carlaw and Bekar 2005, 98).

One of the facts if not the most important one that set a technical change apart and placed it in the exclusive category of GPT was that it generated economic growth. Any improvement in the efficiency of moving people and goods promotes trade, exchange of information and specialization in production. In short cheaper transportation generates what has come to be called, perhaps unjustly, Smithian growth (Kelly 1997, 939-52). Adam Smith gets the credit since he argued emphatically at the beginning of his *...the Wealth of Nations* that the division of labour generates economic growth and that the extent of the division of labour depends on the extent of the market. For him, writing at the beginning of the Industrial Revolution, «water carriage» was the greatest source of that division of labour and so improvement of skills and specialization in production (Smith 1937 [1776], 3-21). The three-masted sailing ship, through the mechanism Smith described, offered a wide range of new opportunities for economic growth.

The standard pattern of the evolution of GPTs historically in terms of adoption and impact has followed a logistic function. It is both the way to view the typical pattern of adoption of almost anything new but also the typical pattern of diffusion where there is a limit on capacity. GPTs begin as crude adjuncts to existing practices and so in their early stages are of sharply restricted use. Experiments and elaboration of the potential creates a wider range of characteristics and, with that, more uses. The spread of knowledge of the new method involves more users and so more improvements which in turn makes the GPT more efficient and more sophisticated. The advantages and greater use means a greater impact on other technologies which adjust to exploit or supplement the GPT. At the same time new activities become possible. The impact depends, then, on any interaction with other technologies which includes the decline in use of predecessors since the new way or ways of doing things are superior. The pace of adoption and hence the slope of the logistic curve depends on a number of factors, not least of which is who controls knowledge of the GPT. If no centralized control exists then there can be easy access to the GPT and more rapid recognition of complementarities with other methods. The scale of efficiency improvement introduced leads to changes in the political and economic circumstances, so easing the adoption of the new GPT. More than that, there is a greater impact on social and economic structures and more rapid adoption of other related technologies. In the entire process along with potential limits to the spread of knowledge and restrictions to adaptation of the GPT and related developments, there is always an assessment of risk that all those involved must make. The novelty or difference from past practice the harder it is to identify the level of risk (Lipsey, Carlaw and Bekar 2005, 379-80; 409-10; 432-34).

The concept of general purpose technologies has the advantage of pointing to certain critical factors in the development of technology and the economy. It draws attention to why certain technological changes are more important than others. It suggests where to look for forces restricting or directing patterns of technological development over the long term. It indicates what to look for in examining the history of technology. It points to risk that is always important to innovators though sometimes can be difficult to calculate or assess. In addition, with all technologies there is constant uncertainty with the potential for exogenous events to destroy any sensible predictions. Uncertainty prevails and pervades all aspects of technical change and with GPTs that is especially true because of the scale and range of their impact. If nothing else, there is the threat of the emergence of a new, competing, superior GPT.

The pattern is one of slow adoption at the start with prototypes or early versions able to compete only to limited degree with existing technology, probably in certain niches in the economy. There is then rapid adoption over relatively short time along with long term spread of the new method. Then there is a levelling off as practice becomes so widespread that the users and producers of the GPT come closer to the limits of what it can do and what related technologies can do to supplement or aid in its use. At that point typically if not before another new GPT or GPTs appear to supplant the original one. The pattern applies in many ways to the three-masted ship, a congruence that unfolds in a description of the character, the pace and extent of adoption and the impact of the general purpose technology in terms of the three phases of the logistic curve. The role of seaborne transportation improvements in the general development of the economy becomes more transparent by following the central features of what Lipsey and his co-authors called a general purpose technology.

2. The First Phase: foundations for expansion of the scope and volume of trade

The first phase stretched from the fourteenth century to the early decades of the sixteenth. It was marked by what, some years ago, this Canadian medievalist called «the great invention» of medieval and Renaissance maritime history: the emergence of the three-masted ship (Unger 1980, 216-30). The development of the design led over time to dramatic changes in the world economy and in geopolitics. As always, it seems the historian writing now has predecessors. The English entrepreneur and explorer Sir Walter Raleigh, in about 1605, talked of the invention of ships along with other sea-faring technologies as critical to the power of states and to economic well-being. For him:

> [...]whosoever commands the sea commands the trade; whosoever commands the trade of the world commands the riches of the world, and consequently the world itself (Raleigh 1829 [1605?], 325).

A new design for sailing ships emerged in the fourteenth century which evolved over the next one hundred and fifty years, coming over time to dominate long-distance seaborne transportation. There were precursors. The ability to power a vessel on water by using a sail was known for millennia and the ability to do that over open seas was known at least by 12,000 years BP. By the thirteenth century there was a range of existing technologies for shipping under all kinds of conditions and on all types of waters around the world. The melding of varied practices in different places proved to be a slow process.

The sailing ship inherited in the Mediterranean from the Roman Empire had undergone a dramatic change in hull construction in the early middle ages. The shipbuilder in charge determined the shape of the hull by the design of the principal frames. Set on the keel at the start of construction, carpenters shaped the hull planks to fit those frames. The smooth surface created lowered resistance. Carvel-built hulls with strength coming from the internal framing saved on labour inputs and very probably on quantities of wood required. Repairs were easier relative to other types of construction. Power to move the ship came through triangular or lateen sails, another inheritance from the classical world. The rig made sailing closer to the direction of the wind easier and decreased delays from contrary weather. The principal disadvantage was the sizeable crew needed to handle the sail type and the need, when coming about to sail in a different direction, to carry the whole sail and its long mast over the masthead. The need for that manoeuvre limited the size of the mast. The sail could not be shortened or extended. The only way to change sail area was to use a different sail and yard so ships had to carry differently sized sails or accept the limitations of having only a default sail available. By 1300 the Mediterranean sailing ship could make trips from Iberia to the Levant without stopping.

They could carry hundreds of passengers from Italy to the Holy Land. For some purposes shippers used galleys which had the advantage of being able, at least for short periods of time, to rely on oars for propulsion. That was especially helpful in getting in and out of port. The vessels had low freeboard so had trouble in the open ocean in any storm. Only the largest of galleys could survive a trip from Italy to the Low Countries. Their greatest shortcoming was the high cost created by the relatively massive size of the crew (Pryor 1994; 1988, 25-86).

Northern Europe had followed a different path. There galleys had all but disappeared by the fourteenth century, especially for commercial voyages over seas. Outside the Mediterranean, tubby sailing ships powered by a single square sail dominated seaborne commerce. Shipwrights built the hull up from the keel piece by piece, overlapping the planking to assure watertightness and strength. The clinker-built hull was heavy and required extensive skills on the part of each shipwright (Adams 2002, 53-58; Crumlin-Pedersen 2009, 148-60; McCarthy 2005, 55-81). The rudder was fixed to a straight sternpost, not to the side of the ship as in the Mediterranean. The cog is the best-known type of the northern European ship, coming to take a major role in shipping in the Baltic and North Seas (Crumlin-Pedersen 2000; Ellmers 1994; 2010: Jahnke 2011: Jahnke and Englert 2014; Paulsen 2016, 122-37).

In the late thirteenth and early fourteenth century there was increasing contact between northern and southern Europe by sea, contact that led directly to the development of the full-rigged ship. Mediterranean shipbuilders redesigned the cog, giving it a carvel-built hull. They then added a small lateen sail near the stern. This two-masted carrack had all the advantages of the northern cog with the additional attribute of being able to sail closer to the wind because of the triangular sail near the stern. The vessel was better able to hold a course and also could manoeuvre more easily. The last touch was to put a small mast near the bow and put a square sail on it to balance the lateen on the mizzen mast aft. The master of the ship had even greater control as a result. The exact date and location of the combination of earlier technologies is not known but already by 1400 builders knew the essential components. The Atlantic coast of Iberia is the most likely site for the earliest full-rigged ships.

While it existed by 1400 the design was still not able to compete with many other more traditional forms and the full potential of the full-rigged ship was not yet explored. The potential for saving labour took time to realize. The lateen sail and the still large size of the single square sail on the mainmast kept crew size up. Over the following two centuries builders divided the sail plan. The total sail area stayed the same or increased while the number of sails grew with each smaller than the typical sail of high medieval European ships. With smaller sails crews handled them one after the other and so fewer men were needed for a vessel of the same size. Smaller crews meant greater range over the oceans of the world. Over time shipbuilders developed different designs for different purposes. Carracks were tubby with a deep waist and high castles at bow and stern. Galleons, which owed features to galleys, had straight gunwales and were narrower which increased speed, eased handling of cargo and improved ability to control the vessel (Phillips 1994; Unger 2019, 44).

It is hard to measure the improvement in safety that full-rigged ships brought.1 Similarly it is hard to measure any change in the cost of transport the full-rigged ship might have brought because so many factors determined the price shippers paid at any time. At least there are measures of labour productivity, though with their own flaws. They show improvement over time, however slow, in the early days of full-rigged ships (Lucassen and Unger 2011). The limited data suggest that single-masted ships in the Baltic had manning levels that it took full-rigged ships more than another 100 years to match. The figures are solely for Europe, the only part of the world that knew full-rigged ships in the fifteenth century. That situation changed when, exploiting the greater range of the type thanks to its potential higher carrying capacity and declining crew sizes, Europeans in full-rigged ships travelled across oceans down the coast of Africa, to the other hemisphere and to and through the Indian Ocean in the late the fifteenth century.

Important to the development and success of any technical innovation is, at the least, government indifference and at best government support. The full-rigged ship, after an initial period of experimentation, enjoyed positive institutional promotion. Various states subsidized the exploitation of the design in voyages to distant and even unknown regions. In the first half of the sixteenth century there was an arms race among northern European states with kings paying for the construction of ever bigger naval vessels. The kings of France, England, Scotland and Denmark all found that there were limits to how big such ships could be. It was expensive to build the giants and also costly to find and maintain the massive crews that the vessels needed (Unger 1980, 234-35). Realizing the advantages of the type, governments also built ships which were of little use for carrying cargo but were effective as fighting platforms. Light fast galleys had long qualified as specialized warships. Through the sixteenth century governments increasingly used full-rigged ships to fight at sea, in the process exploring effective changes in design and construction (Unger 1981). In promoting voyages of exploration and, from the early sixteenth century, voyages to carry emigrants to the Americas as well as Asia governments expanded the use of full-rigged ships and also increased the numbers built. They gave shipbuilders more opportunities to hone their skills in producing the type while also giving occasions to try variants. All the time through the first phase down into the sixteenth century the design became better known, the ability to create examples of the type spread and the use of the vessels that fit the description increased not just on the open ocean but also in the Baltic and North as well as the Mediterranean Seas.

[1] The McCormick et al., *Geodatabase of Shipwrecks* ends in 1500 and shows a maximum of 23 cases in the century after 1400 and 20 for the century after 1200. In both cases some of the ships may have gone down in the following century. While the figures are suggestive, the small sample size and the lack of certainty about date of loss or the design of the ships involved, among other things, drawing any conclusion would be overly ambitious.

3. The Second Phase: improvements and impact of the general purpose technology

From the mid sixteenth century to the early years of the nineteenth use of full-rigged ships expanded. The areas of the world where the type was found and built increased to encompass all of the oceans of the world. The variants continued to grow with some standardization in subcategories of the full-rigged ship. Designs took advantage of the qualities of the essential features of the type while adjusting features to suit specific trades. Shipbuilders throughout Europe learned to produce full-rigged ships, in some cases hesitatingly staying attached to older practices which gradually faded away (Unger 1985; Maarleveld 1994a; 1994b). By the eighteenth century, methods of building were consistent everywhere with variations dictated by the trades, functions and places where the ships would find use. The sailing ship was a lumpy investment and while land had the greatest share of total investment it was highly divisible. The risk of loss of such a valuable capital good, a risk that was in large part determined by conditions at sea, was a brake on the pace of technological advance. Buyers of ships and so shipbuilders were leery of novelty. If that was not enough the general uncertainty which accompanies all technological change, the ability of exogenous political and social developments and spillovers from existing technologies to have an impact on the shipping sector as well as the economy at large always served as deterrents to experiment for investors and shipbuilders.

To counteract misgivings there was a varied collection of changes in full-rigged ships in the sixteenth and seventeenth centuries which improved their performance and so promoted the adoption of the type. The continuing success with dividing the sail plan along with the addition of sails of different types, while somewhat increasing the levels of skill needed for crew members, did improve speed, safety and efficiency. Hull shapes continued a process of increasing length relative to width. That made it possible for ships to be larger but also more seaworthy. Builders overcame the tendency of long ships to hog, that is for the ends to sag, not quickly nor completely but enough to improve efficiency in shipping. Greater use of block-and-tackle on board to handle sails and widespread use of capstans to handle anchors and in the loading and unloading of heavy cargo helped in lowering crew size. Perhaps most effective in lowering costs was the emergence of vessels with features suited to one trade or one set of trades. The growth in certain exchanges of goods meant building specialized vessels with designs to suit those trades paid off for both the shipbuilder and the shipper. The Dutch fluyt which emerged in the last years of the sixteenth century was perhaps the outstanding example, at least in northern Europe. Used extensively in the grain trade to the Baltic and to southern Europe, it was longer relative to its width than its predecessors and had a simple sail plan so crew size was kept low. The type could deliver improvements on the best manning ratios of the best-performing competing designs of the end of the middle ages and so replaced them in many northern European trades while being able to compete in transoceanic ones. Dutch builders produced other specialized types and the general development extended to vessels for the fisheries and, in time, to warships (Wegener Sleeswyk 2003b).

The size of individual ships did grow though sailing vessels do not obviously or immediately benefit from increases in scale. The benefits of size may disappear if there is greater danger of loss since bigger ships increase the concentration of whatever loss occurs. It was difficult to know a priori the range of the scale economies and dis-economies, in part because of the inability to accurately assess potential for loss and in part because of the potential impact of constraints such as depth of waterways and ports. Larger ships might mean savings when holds were full but there were no guarantees that vessels would frequently if ever be at maximum cargo. In the trade to the East Indies, because of the considerable profitability, ships were full and even overloaded much of the time. Errors in shipbuilding, such as using wood not properly aged, could generate massive losses as Portuguese shippers learned in the years around 1600. Those same shippers and their government identified the problems and reduced their losses to the norm for their competitors. For all trade around the Cape of Good Hope finding the optimal ship size was something worked out through experiment. A bigger ship almost always meant greater carrying capacity. It also meant a greater investment since big ships cost more to build and apparently more per ton as well. They were often faster and had a lower ratio of crewmen per ton so there were benefits from larger ships under certain circumstances (Wegener Sleeswyk 2003b). Larger vessels required adjustments in building and in some of the materials used which helps explain the higher construction costs. There were significant changes to handling qualities and ways to sail a vessel as size grew suggesting that there was an optimal size above which returns to investment declined, a discovery made in the East Indies trade and in others over the course of the second phase (Lipsey, Carlaw and Bekar 2005, 390; 396).

Technological improvements in the second phase were subject to constraints, some internal to shipbuilding and others external. As anticipated the gains were less dramatic than in phase one and the pace of efficiency gains went down over time in phase two. The greatest added value with general purpose technologies and very probably with any technology comes from the replacement of existing methods with the new ones. In the case of the full-rigged ship the efficiency improvements came from replacing the capital good, that is the ship itself. Over time many types such as cogs in northern Europe to lateen-rigged feluccas and xebecs in the Mediterranean became smaller and their use more circumscribed. The numbers of full-rigged ships rose in the new trades created by their versatility and efficiency but also rose in traditional trades. The use of newer technology spread as shipbuilders modified and improved their products. An obvious result was gains in labour productivity in shipping during the seventeenth and the eighteenth centuries which were higher than in almost any other sector (Lucassen and Unger 2011, 17-22). The potential gains attracted capital investment which also fuelled the replacement rate in ships. It also meant producing vessels that could operate in previously under-developed trades. The addition of gunpowder arms and the improvements in hulls so ships could carry artillery, made lighter by the end of the sixteenth century because of the introduction of iron guns on board, opened operations in dangerous trades and the possibility of intimidating competitors around the globe. Other increases in the capital invested in certain ships had less dramatic effects on the spread of full-rigged ships, though, reinforcement of hulls made possible operation in Arctic waters which opened a number of sites to whale fisheries and, in the late eighteenth century, the addition of copper sheathing among other improvements promoted longer life and higher speeds for ships operating in tropical waters in the East and West Indies (Kelly, Ó Gráda and Solar 2021; Solar 2013; van Zanden and van Tielhof 2009; Rönnbäck 2012).

3.1 Spillovers

One obvious spillover from the more extensive use of full-rigged ships, their growth in size and the prosperity of shipbuilding was the scale and stability of construction sites. Where in the middle ages there were few permanent shipyards, certainly in Europe, and what few there were served for the construction and repair of galleys in the Mediterranean. Starting at about the same time as full-rigged ships some towns in northern Europe set aside land for shipbuilding. Through the sixteenth and seventeenth centuries the number and size of those sites increased considerably (van der Vliet 2006). The choice was recognition of the expansion of the industry and also recognition of the greater needs of craftsmen. The greater efficiency in shipbuilding also depended on improvements in related technologies in shipyards. The use of cranes made moving timber easier but they and the greater size of the varied shapes of pieces of wood increased the space requirement. Improvements in metallurgy made the tools in use more durable. The number and variety of tools along with the permanence of sites translated into more storage space on the wharves.

The greater demand for information about places throughout the world and how to get there generated pressure for improvements in navigation. By the thirteenth century cartographers in the Mediterranean had pieced together data on compass readings and distances from port to port along with sailors' sketch maps of local areas to create large impressive portolan maps of the Mediterranean. While those valuable maps indicated the potential of cartography it was smaller and rougher maps along with books with sailing directions that made their way to sea, serving there as aids for working seamen. By the sixteenth century printed maps in collections, charts of various regions large and small as well as instruction manuals appeared and enjoyed wide circulation (Lang 1968; 198; Schilder 2017; Waghenaer 1965). There was an increasing market for the materials among students going to the navigation schools which began to spring up in port towns (Burger 1908; 1909; 1910; Craig 1982; Schotte 2019). Port towns became home to the makers of nautical instruments who improved the quality and availability of their products. The combination of better devices to measure the position of the sun and the stars and useable and increasingly accurate charts made it much easier for pilots to fix the position of their vessel at sea. Governments took an interest in tracking the latest information about distant sailing routes in the sixteenth century as Iberian sailors ventured to seas in many parts of the globe previously out of the reach of Europeans. State offices gathered the information both for the safety of ships at sea and to establish territorial claims. The commissioning of cartographic surveys and the production of maps may have had political motives but those efforts that, by the eighteenth century, stretched from the Mediterranean to the eastern Baltic were the foundation for government hydrographic offices which emerged in the early nineteenth century (Lang 1968, 50-66; Unger 2010, 76-78; 99-102).

The full-rigged ship generated spillovers to the handling of cargo in port towns. Facing increasing volume of trade and larger ships, civic authorities improved the organization of handling cargo on the wharves. They established institutions to organize teams of experienced longshoremen available to handle cargo when needed. They made provision for storage on wharves and for easier access to the docks for the carts and wagons that took away cargoes. Wharves increasingly had cranes of growing size to ease the work and increase the scale of moving goods from ship to shore (Lucassen 2011; Stern 1960). All those improvements were responses to the changes in ship design. So too were the many cases of towns moving docking facilities further downstream if they were on rivers to be closer to open waters. Larger full-rigged ships with deeper draft needed more space to manoeuvre and for lighters to reach them (Unger 2006b).

The spillovers from port improvements and better navigation promoted more regular trades carried out more quickly which in turn improved communication and also promoted the development of other designs of smaller ships to supplement the long-distance trades using full-rigged ships. While sending information overland was always faster than travel by ship, in cases such as contact between the Americas and Europe or islands around the world the full-rigged ship was an invaluable source of connection. The frequency of voyages over shorter distances might not speed the transfer of urgent information but the volume and range of news expanded along major routes. Advances in specialization of ship design were already underway before the full-rigged ship emerged but the new design accelerated the process as the three-masted. and for a short time four-masted, ship took over an increasing share of longer distance trade. Those smaller boats and ships, some with only one or two sails on a single mast, served to distribute good to and from major ports to lesser ones. In some cases those craft of different design or variants on the full-rigged ship could find use in long distance trades (Unger 2019). Gains in efficiency from technical change in smaller vessels in the second phase and beyond was considerable, advances promoted by the success of long-distance commerce. The pattern of trade reorientation enhanced the tendency toward specialization in design but also among ports. The marshalling of goods at a single site shortened turnaround times and improved utilization of carrying capacity. It also meant that certain centres grew more quickly and so promoted communication and with that the potential for technological advance.

The spillovers and the effectiveness of the full-rigged ship generated a range of connected changes in commerce and settlement. The opening of new trades and trade routes led to an increase in production and also to redistribution of settlement in Europe and in many other parts of the world. It was in long distance seaborne trade where the impact was most obvious. By the early seventeenth century Dutch shippers had found ways to sail between Europe and the East Indies on a more regular basis and in shorter times. Their success and that of their English counterparts sailing to India led directly to a sharp increase in the volume of trade between Europe and Asia and the erosion of overland exchange across Eurasia (Bruijn 1990;

Steensgard 1990; Lane 1940). By the 1620s, for example, Venice had surrendered the role as distribution point for Asian spices to Lisbon and Amsterdam. Spanish navigators learned enough about prevailing wind patterns in the Pacific to establish somewhat regular contacts between Mexico and the Philippines. Volumes might have been small, though, it was a novel trade and a source of the growth of Manila as a port (Giraldez 2015, 101-59).

Already in the sixteenth century exchange of goods carried in full-rigged ships led to reorientation of the trading networks of Indigenous Peoples in North America (Trigger 1986, 111-63). Over time in the Americas the arrival of migrants from Europe and Africa, often sponsored by governments in one way or another, led to implementing new agricultural practices. The trade with more distant places, at first with Europe and increasingly with other sites in the Americas, promoted specialization in crops raised. The settlements of the migrants were largely along or very near the sea coast so easily serviced by sailing ships that, for Atlantic crossings, were largely three-masted vessels. Throughout the world and especially in Europe cities on the oceans saw faster growth than those in the interior. The most prominent examples were ports in Europe such as Seville, Lisbon, London and Amsterdam (Bairoch, Batou and Chèvre 1988, 130-33; 176-88)

The development and continued elaboration of fill-rigged ship design led to spillovers in the organization of the industry that produced the capital good. The great majority of building and especially the building of smaller vessels was in the hands of private investors. By the seventeenth century, though, a few private shipbuilders were moving toward operations on a larger scale with investment in permanent yards and tools and equipment, investments made possible by the volume and value of ships built along with the rise in orders for larger ships. Dating from the late middle ages guilds of independent producers, organizations given legal status by towns, brought together the owners of wharves who were skilled labourers. Not common in areas outside northern Europe, those institutions oversaw training in the techniques of the trade and offered a rudimentary system of grading levels of accomplishment. The guilds then gave shipcarpenters an easier path to move to other towns and in the process increase their own knowledge while disseminating information more broadly. By the seventeenth century the role of those institutions decreased in importance, in part because the need to spread technological innovations declined and the scale of construction grew. The concentration of authority in the hands of the designer of the ship led to a deskilling of workers on the wharf and reduced the need for training.

That tendency was most notable with the rise of government-owned and managed shipbuilding facilities. Such yards predated the full-rigged ship with examples in the Mediterranean, most notably in the Arsenal of Venice. There were also yards in which the state had an interest in China as well in the sixteenth century and before (Moll-Murata 2008, 182-83; Lane 1973, 361-64). The expansion of the responsibilities of governments and the appearance of monopoly trading companies in northern Europe, both in part due to the changing technology of shipping, centralized work for larger ships. They also created pressure to increase the size of ships. The resulting yards, like that of the Dutch United East India Company (VOC), were among the largest industrial enterprises in the world.

4. The Third Phase: flattening the curve and decline, still with technological advances

The rate of adoption of the full-rigged ship levelled off in the eighteenth and nineteenth centuries. The prevalence of the type was so great in most parts of the world that the functions for which it was best suited were overwhelmingly dominated by vessels of that design. There may have been a slight erosion in the number of full-rigged ships in use in the part of the world where it was first developed. Newer versions of other types, influenced by the hull design, rigging and construction methods of full-rigged ships, found certain trades and uses where they could supplant the dominant type. The larger size of two-masted ships and their greater sail area along with greater ease of handling sails was a case in northern Europe where, in some trades, full-rigged ships were replaced. Ultimately it was the emergence of a new technology for the propulsion of ships at sea that led to the fading in importance of the GPT with roots in the fourteenth century.

There continued to be improvements in technology of sailing ships though they were not on a scale or of the complexity of the advances in phase two. The addition of small studding sails on extensions to the now many yards that decorated taller masts, set only in good weather, could mean some greater speed. More important was the gradual change from a lateen sail on the mizzen mast to a gaff sail, called a spanker or a driver, which eased handling of that fore-and-aft sail and made possible its increase in size. There were more staysails to take advantage of the presence of standing rigging from which those sails hung. In general, the maximum quantity of canvas on a full-rigged ship went up (Unger 2011). The greater source of energy was especially valuable with warships as they grew in size (Glete 1993). The wars among states in western and northern Europe generated something of a naval arms race to gain some control over the seas which translated into bigger ships to fight in pitched battles as well as into faster, more versatile warships of middling size (Unger 2006a). The importance of naval conflict also created government interest in finding out what the competition was doing, in acquiring the latest technology through importing shipyard workers from regions that led in naval architecture to using spies to report on how other states built their warships (Harris 1998, 25-26; 425-52; 523-39; Ferreiro 2007, 63-68). Even stretching back into the seventeenth century the armed full-rigged ship with higher costs of construction, fitting out and manning, had forced evolution on governments. Just as the growing sizes of armies and their increasing costs in the sixteenth century had placed greater burdens on governments so too did navies. What historians have called the fiscal-military state which emerged in the period, devoted to finding income sources to finance forces for war, was to a significant degree a result of technological developments in shipbuilding. While there were signs of that evolution of European states before the eighteenth century the increasing size of warships, the larger crews, the permanent bases for them all combined in the eighteenth century to expand the scope of government action, the range of activities of states and make the protection of seaborne commerce a principal goal of government action in both war and peace time (Bonney 1999; Glete 1993; Unger 2015).

New technologies began to have their effect on the full-rigged ship. Metallurgical advances made it possible for shipbuilders to turn to iron supports in place of wooden ones to reinforce the heavier hulls. As iron and then steel production rose in the nineteenth century builders built entire hulls from metal instead of wood. The new general purpose technology with extensive and long-term impact, the steam engine, had a lasting effect on sailing ships. By the third quarter of the nineteenth century the majority of the tonnage of western Europe merchant marines was powered by steam. Faced with competition from steam power, through much of the third phase the pace of technological advance in sailing ships grew, the improvements following the earlier paths toward labour saving and lowering risk (Rosenberg 1972, 26-8). The impact of steam engines already came early in the century, though, and provided a significant advantage for sailing ships. Getting in and out of harbours was always a problem no matter the sail plan. The vessels had to wait for favourable tides and winds and, in extreme cases such as the monsoons winds in the Indian Ocean, delays that could last months. Steam-powered tug boats could tow sailing ships to open water where they could operate freely, cutting down on travel time and making the timing of departures and arrivals more reliable.

The transfer of the sailing-ship technology first developed along the Atlantic Ocean coast of western Europe in the late middle ages started in phase two as full-rigged ships travelled to sites around the globe. The sharing of the design and construction methods became more obvious, however, in phase three. The extent of that transfer was slow, a reflection of the lack of institutions to carry out dissemination and of the quality and character of existing technologies in other parts of the world. The gains from switching to the imported design were in Asia too small to convince builders in India, China, Japan, southeast Asia and the islands in the Pacific to take on what was an unfamiliar type of construction requiring, in many instances, skills different from those they had (Lewis 1994). In Australia, southern Africa and the Americas the full-rigged ship was so different from the existing vessels that entirely different forms of transportation continued to operate in their own spheres. The great difference in technologies made any bridging of the gap impossible and so the full-rigged ship dominated long distance transport and the carriage of large quantities of goods. In China and Japan traditional vessels remained in widespread use, preferred over full-rigged ships. Junks built in Chinese shipyards proved to be as effective as full-rigged ships in many trades, so much so that Europeans used them on occasion as well (Manguin 2010; Unger, 2013, 164-87). In India there was more borrowing of imported technology in the overall design of seagoing vessels and in the specific methods of fastening. Nails replaced tying planks one to the other, though, the cost of iron slowed the transformation (Manguin 2019, 401-03; 407-12; Staples and Blue 2019; Vosmer 2019). In the islands of southeast Asia full-rigged ships operated alongside smaller vessels of designs familiar in Europe alongside those of traditional local design, both used by the dominant European trading company. Europeans, in some cases, found locally-built large trading vessels to be as useful as ships of their own design (Manguin 1993, 265-74). Some cross fertilization existed though that was more obvious in and around the Arabian Sea. There shipwrights maintained the general principles of traditional construction though they added features borrowed from the full-rigged ships operated by European traders, a practice which gained ground during the second phase. One obvious example was the *baghla*, a large ship from 200 up to 1000 tons that below the waterline was shaped like a traditional Arab vessel but which above had many European features (Agius 2008, 153-67; 310-48; Agius 2002, 34-70; 133-87; Al-Salimi and Staples 2019, 45-46).

Maritime states on the European Atlantic front established shipbuilding yards at strategic sites for warships and also for cargo ships in many parts of the world. The principal function of the facilities was the repair of vessels after the implied long voyages from Europe. The presence of those yards from Batavia in present Indonesia to Elmina in west Africa to Paramaribo in present Surinam and many places in between those sites offered examples of how to repair and build ships of European design, full-rigged but also smaller ones. Often the shipwrights brought from Europe had to use local materials and so in the process gained an appreciation of the value of different kinds of wood, for example. The yards typically employed local workers who were often the unskilled labourers there but they had opportunities to learn about full-rigged ships. The imported carpenters learned about local designs and practices as well. The transfer of information was not just in one direction (Antunes et al. 2019). Still through the third phase while any exchange of knowledge of the technologies was limited, it was the development and articulation of the full-rigged ship that created any opportunity for learning. It was in the nineteenth century when the new technology of steam power replaced sails for propulsion that the distinctions among different designs and building practices around the world slowly faded away.

In the third phase, as the influence and importance of the full-rigged ship was declining, the art of ship design and shipbuilding became more formalized, standardized and institutionalised. Methods of knowledge transfer become better. The structure of knowledge about practices in the trade expressed in written works over time improved, at least within the region where the full-rigged ship began. Still, the relationship of the advances made in ships with the institutions, formal and informal, set up to administer shipbuilding in different parts of the world, illustrates the minor role of written works on the topic and the lack of any systematic objective discussion of the practice of the trade until the eighteenth century. Already in phase one, in the fifteenth century descriptive works about shipbuilding and work in shipyards started to appear (Michael et al. 2009). Such books changed over time to careful descriptions of types of construction, works that could be sources of guidance for practising the trade or for apprentice shipbuilders. They became more detailed and came to adhere more closely to practices of the day. They indicate exchange of knowledge and the growth of building traditions (Cazenave de la Roche 2020, 7-22). By the end of the seventeenth century such works, still limited in number, appeared in many parts of Europe. In the eighteenth century, authors tried increasingly to give ship design a more rigorous method through the use of mathematics. It was another case of science having an impacr on technology. In the spirit of Newton, the books on shipbuilding were filled with formulæ and geometric drawings. Controlled experiments with types of ships were rare but they did exist. The texts were required reading and their contents the basis for instruction in the first and short-lived schools for shipbuilders in the second half of the eighteenth century (Ferreiro 2007; Mokyr 2018, 15-17). Through into the nineteenth century the works of mathematicians meant to bring order to the understanding of shipbuilding. Their ability to summarize the technology in a consistent manner indicates a certain ossification of methods and practices. Even so knowledge of how to get the most from the hull of a sailing ship increased dramatically in the nineteenth century, illustrated in published theoretical works on what had become a science of shipbuilding (Ferreiro 2020, 23-55). One remarkable result was the fastest full-rigged ships ever built.

With the full-rigged ship productivity gains came as it supplanted the types that had carried on local and regional shipping tasks, first within Europe and then around the world. While the development of new all-sea routes connecting the varied parts of the globe might have been more dramatic and imply some of the greatest impact of the new technology, the economic importance through the second phase came more from replacement of the range of sailing ships that was in use. As builders refined the design of full-rigged ships and found ways to produce specialized vessels the new type invaded more of the established trades. That importance increased through the second and into and through the third phase. The shipping patterns that the full-rigged ship opened and the shifts in production and populations as a result of the development of the full-rigged ship made possible a sharp increase in global commerce and so a sharp increase in the total number of full-rigged ships in service. European merchant marines grew dramatically through the eighteenth century and hardly flagged in that growth, it seems, in the nineteenth (Unger 1992). Almost contrary to expectations, it was then in the third phase, with established routes and rising populations made possible by trade, that the economic effects as well as political and military ones of full-rigged ships were greatest.

5. The long tail of the logistic curve

Just as with the emergence of the full-rigged ship in the fourteenth and fifteenth centuries the decline and replacement of the type took a considerable time. There were precursors that paved the way to the «great invention» just as there were various successors in the nineteenth and the twentieth century to the full-rigged ship. Even though builders found ways to power river-going craft with steam engines in the first years of the nineteenth century, the sizeable fuel requirements and uncertainty about stability, apprehension created by having a very heavy engine on board, limited the scope of use. In its first stages the new technology required a number of improvements and refinements to compete with existing vessels. Steamship use began with tugs and river craft. This spread to ferries inland and then to short distance services on the sea. Over time the length of voyages increased and steamships replaced sailing ships on ocean going routes. The process was a slow one, however. It was not until the 1870s that the majority of tonnage in the British and the Dutch merchant marines was steam powered. It took that long before steam engines were efficient enough and for spillover effects in the facilities in ports and the opening of new waterways made the choice of steam the logical one. As important were the continuing improvements in speed and manning requirements of full-rigged ships and their impressive descendants which kept them competitive. On some routes where the winds were reliable and commodities established, such as from Europe to the west coast of South America going around Cape Horn, sailing ships remained in use well into the twentieth century.

For millennia sailing ships provided a way to use the wind to move goods and people. In a world where kinetic energy in any form was rare, those vessels going over water opened an otherwise impossible range of possibilities. It was only in the late eighteenth century that the steam engine offered an alternative on land and on water. The low energy levels demanded by sailing ships, the free availability of power and no need to carry their fuel with them gave those craft reasons to continue in use for decades after the new general purpose technology appeared. Steam engines and especially the inefficient coal fired ones of the early years of their use had negative environmental effects but at a scale so limited as to be unrecognized. In the absence of a tax on carbon dioxide emissions the advantage that sailing ships had in their minimal impact on the natural world did not affect decisions on whether to use sails or steam to move ships.

The advances in shipbuilding, including the improvements in design, along with the related developments in various shipping technologies, made a considerable contribution to the long-term growth of the world economy between the fourteenth and the nineteenth centuries. The lowering of transport costs and the opening of new avenues for trade laid the groundwork for specialization in production and as well as the introduction of new goods to otherwise unreached markets. Technological changes also led to better preservation of the capital good and so decreased losses and increased returns to investment, valuable in a capital-poor world. Because of the impact of more efficient and more versatile ships, new forms of organization emerged in shipbuilding with large scale durable facilities and in commerce with joint-stock monopoly trading companies in Europe. In the early phase and in the era of dominance of full-rigged ships the shipping sector offered sources of growth and resilience for the economy. That attribute was especially obvious in the face of serious threats from environmental factors in the fourteenth and again in the seventeenth century. That was even more true over the long term for certain parts of the world where the technology came early and was best exploited. The three-masted ship and the multitude of spillovers from that development of a more efficient variant of an established technology, one using wind as a source of kinetic energy, qualifies and, indeed, almost defines not only for the late middle ages and the Renaissance but also for the history of the last dozen or more millennia what a macroinvention or a general purpose technology was and is.

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Productivity? – Yes, but subject to sustainability!
An evidence of (re)emergence of accounting for sustainability from the French agricultural authors from the XVIIth to the beginning of the XIXth centuries

1. Introduction

The topic of accounting for sustainability is relatively recent in management sciences research: the first works and researches date back to 1970 (Christophe 2000; Gray 2007; Richard 2012b). As Gray (2007, 187) said, accounting for sustainability research «has grown, in a relatively few years, from a very marginal area of interest and practice to a diverse and vibrant area of research, teaching and practice».

Agricultural production is closely linked to, if not completely dependant on, nature. Moreover, at the present time, the environmental impact of agriculture is not less and sometimes even much higher than the impact of industrial enterprises (Kafadaroff 2008). That is why this economic sector proves to be a very interesting research field in the view of sustainability.

We chose to focus on French literature on agriculture for two main reasons: 1) for a long time, this country is an agricultural power (Parmentier 2009); 2) in France, there is a fertile ground for the historical research given a rich literature in agricultural accounting since the 16th century, and given preserved archives of some State experimental farms. Historically, works on agricultural management (de Serres 1651; de Cazaux 1824; Mathieu de Dombasle 1824-1832; Bahier 1860; Degranges 1909) are among the first French publications in accounting and management.

However, a depth analysis of agricultural accounting has been the subject of few in number research, notably in France (Lemarchand et al. 2017; Giraudeau 2017). So, agricultural accounting deserves an investigation in light of sustainability issues.

The fact that in France, in agricultural sector, scientific methods concerning a consideration of natural processes have been developed since long – for example, Ciriacy-Wantrup (1938) testifies that already from the time of feudalism in France (in the form of «manoir») an issue of soils conservation was of great importance, – leads us to question a very emergence of accounting for sustainability, notably for

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Referee List (DOI 10.36253/fup_referee_list)
FUP Best Practice in Scholarly Publishing (DOI 10.36253/fup_best_practice)
Yulia Altukhova-Nys, *Productivity? – Yes, but subject to sustainability! An evidence of (re)emergence of accounting for sustainability from the French agricultural authors from the XVII to the beginning of the XIX centuries*, © Author(s), CC BY 4.0, DOI 10.36253/979-12-215-0092-9.23, in Giampiero Nigro (edited by), *L'economia della conoscenza: innovazione, produttività e crescita economica nei secoli XIII-XVIII / The knowledge economy: innovation, productivity and economic growth,13th to 18th century*, pp. 395-416, 2023, published by Firenze University Press, ISBN 979-12-215-0092-9, DOI 10.36253/979-12-215-0092-9

strong sustainability (Daly 1991) respecting physical thresholds characterizing the minimum level of natural capital to be preserved. Is this concept so new?

As Braudel said (1979) about the term of capitalism, and what this paper questions about accounting for sustainability, the concept may have existed even before the term emerged.

For that reason, this paper aims to follow the (re-)emergence of agricultural accounting for sustainability, notably in the French literature from XVIIth to early XIXth centuries, that is even earlier than the term of «accounting for sustainability» existed. So, the research question of this paper is: Are there some premises to strong sustainability in French agricultural accounting of XVIIth-early XIXth centuries?

As in the Kidd (1992), Fressoz and Locher (2020), Cummings and Bridgman (2021) works, we are looking for the answer to a diachronical question related to sustainability: Are the works of French agromen (agronomists-economists) on improving productivity in agriculture respecting strong sustainability principles?

We will show that some French authors in agronomy, rural economy and agricultural accounting of XVIIth-early XIXth centuries dealt with ecological and social issues, even if they did not use the word «sustainability».

Consequently, this paper is structured as follows. Firstly, a theoretical framework and some arguments for choosing a methodology are provided. Secondly, to make a history of the development and diffusion of the agricultural accounting for sustainability means not only to establish a chronology of steps and places of its appearance, but also to come back to the economic and social context which formed the backdrop of this process. That is why we present a social-political context in France for the period under study while discussing some early works on agricultural accounting and management in general. Finally, conclusions concerning sustainability approach in agricultural accounting and management are drawn from this analysis.

2. Theoretical framework, methodology and data

As mentioned by Colasse (2007, p. 28-29), «... accounting... participates in and to the capitalist system, there is interaction between the tool and the system; that's probably the fundamental intuition of Sombart, intuition that retains its heuristic value for many researchers».

This paper is based upon the theoretical background inspired by theories of capitalism and accounting evolution that take into account the socio-political context, where the institutions in their broader sense, include norms, social representations, collective action processes (especially power dimensions), forms and types of exploitation, and governance aspects.

This study is in line with research works which consider accounting as a subjective technique because of its dependance on a subject which has the power (Richard 1980; 2012a; Cooper and Sherer 1984; Tinker 1984; 1985; Hopper et al. 1987; Cooper et al. 1989; Catchpowle et al. 2004; Chiapello 2007; Colasse 2007).

To follow the genesis of agricultural accounting in France, from the strong sustainability point of view, this paper is based upon the historical approach.

Concerning farm accounting, there are mostly historical works on English context (see for example, Mepham 1988; Edwards 1989; Bryer 1991; 2006; Juchau and Hill 1998), but also on the French one (see for example, Garnier 1982; Lemarchand 1993; Cocaud 1999; Depecker and Vatin 2016; Joly 2016a; 2016b; Lemarchand et al. 2017), and the Italian one (e.g., Rossi 2013).

In the field of accounting for sustainability, the works based on historical method are dealing more particularly with the subject of corporate social responsibility, but not in the agricultural sector (Grinberg and Pezet 2006; Pezet and Loison 2006; Loison 2009; Loison and Pezet 2010; Berrier-Lucas 2012; 2014).

That is why we decided to examine agricultural accounting litterature. We realised an observation of farm accounting practices described through selected publications of the period from the XVIIth to the early XIXth centuries.

The choice of this study period is related to available literature: this period is characterized by the emergence of works of prominent French authors in rural economy and agricultural accounting, namely Olivier de Serres, known as the «father of French agriculture», and Christophe-Joseph-Alexandre Mathieu de Dombasle known as the author of the first French manual of agricultural accounting in double-entry.

Three authors were chosen notably because of the popularity of their publications, as well as due to their notoriety: Olivier de Serres, C.J.A. Mathieu de Dombasle, and Auguste Bella. Olivier de Serres' book has been edited 21 times during the XVIIth and XIXth centuries. The 21st edition dates back to from 1804 and was published with Napoléon's support. The C.J.A. Mathieu de Dombasle's books have seen dozens of re-editions, some of which posthumously as well. The accounting model he described, was included in many books and taught in agricultural schools, including the Grignon one, where Auguste Bella worked. The *Annales de Grignon*, signed by Auguste Bella, have seen also many issues (between 1821 and 1849).

Moreover, all of these three authors practiced in and managed their farms (respectively: Pradel domain, *la Ferme de Roville*, and *Institution royale agronomique de Grignon*) that can be called experimental farms thanks to the freedom that these authors had to make decisions and to act.

- The sources that nourish this analysis are diverse and following ones:
- Original documents, such as several contemporary works of the period under study;
- Historical works, including accounting history papers, as well as works on rural, economic and political history;
- Non-historical works which fall under the accounting and control, other disciplines of management, or agriculture topics.

In order to discuss some examples of premises to accounting for sustainability in agricultural literature of XVIIth- early XIXth centuries, it is necessary to examine the socio-economic and political environment of the time.

3. Some examples of premises to accounting for sustainability in agricultural literature of XVIIth-early XIXth centuries

In this section, we will focus on describing, in the light of accounting for sustainability issues, the work of some outstandig figures in French agriculture of the XVIth - beginning of the XIXth centuries who contributed to the emergence and development of agricultural accounting, namely the Olivier de Serres' (1539-1619), C.J.A.Mathieu de Dombasle's (1777-1843) and Auguste Bella's (1777-1856) works.

3.1 Olivier de Serres' work and domain of Pradel

One of the outstanding figures in the history of agriculture was Olivier de Serres. He has been called Father of Agriculture by Arthur Young[1] and other researchers.

Olivier de Serres was among the first persons to practice reasonable farming in the agricultural field of Pradel of nearly 200 hectares, by using crop rotation (crops rotation on the same land in the time). He discovers that the lucerne crop enriches the soil and allows the next year higher yields on the ground where it grew. He cultivated the land himself. The Pradel domain became a laboratory, an experimental farm, where the intuition of agricultural modernity shoots up and where the test administered empirical proof of the validity of inventions (Ardèche, «Olivier de Serres»).

The lord of Pradel was free or substantially free in all of his decisions, which was not the case for the vast majority of farmers of his age: he was the owner. It gave him the freedom to act. Until the nineteenth century, his lessons concern only his counterparts, that is in total quite a few world (Boulaine and Moreau 2002, 17-18). His book from 1600 (*Theater of Agriculture*, in French - *Théâtre d'Agriculture*)[2] contains the innovative feature of developing a management philosophy known as a good father management (*en bon père de famille*), «with the aim of preserving the future of farm while seeking to increase its production » (Boulaine and Moreau 2002, 34). Boulaine and Moreau (2002, 34), bringing together two contradictory words, notice that «Olivier de Serres has made productivity ecology without knowing it».

The book will see eight editions during the lifetime of the author, 19 editions until 1675, and a 21st edition in 1804. The book is divided into eight « places» (chapters) which analyzes the different agricultural and horticultural activities, from the description and organization of the field to the expense of the property by the owner.

The book describes the rational ways of knowing an agricultural land, of cultivating cereals, mulberries and grapevines, of raising livestock, poultry, bees and

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[1] After his visit to Pradel two centuries after Olivier de Serres' death, Arthur Young (1741-1820) gave the finest witness to this agronomist of the sixteenth century: «*I was contemplating the home of the illustrious father of French agriculture, one of the greatest writers on the subject that had then appeared in the world*» (Boulaine and Moreau 2002, 7).

[2] The word «theater» refers to treaties that put theories as if they were characters in a scene (Ardèche, «Olivier de SERRES»).

silkworms, of shaping vegetable, flower, medicinal and fruit garden, of arranging the paysage, and also of how to use food, clothes, furniture and tools. This is to meet the basic necessities of a decent «home» (or «housekeeping») family: food and health, but also the profit and pleasure. The Olivier de Serres' project is quite simple, it offers a serene philosophy:

- to shove an ancient peasant myth of the tired earth who need to rest during the fallow period and wasteland, by replacing it by forage crops improving soil fertility;
- to implement innovative field experiences in the garden by intensifying crop culture: animal manure of the soil, new crop species such as potato then known as the cartoufle or white truffle…, irrigation of meadows, selection of more productive and more resistant to disease varieties; …
- to build "beautiful and good" agricultural buildings; …
- Finally, this book provides some advices to fathers and mothers on how to educate their children so that they know to grow their property (Ardèche, «Olivier de SERRES»).

At that time, farmers are cultivating their land once each two years due to the lack of manure. The rest of the time, the land remained fallow. Thanks to Olivier de Serres, the alfalfa and sainfoin on fallow inaugurate tame pastures.

By reading his book, one can observe some premises to accounting for sustainability. For example, Olivier de Serres (1651) focuses on the importance of care for the Nature and soils, or, for the manner of measuring soil (chapter 3 of the book): «… there is a difference between measures of soils, from province to province…», «… the first [kind of soil], as also the most antic one… is Herbages [grassland]. The second to the Bread that is made from cereals. And the third: to the Wine, from Grapes…» (Serres 1651, 8; 12), that is the distinction of soil kinds and correspondent treatment.

Olivier de Serres (1651, 46; 47) indicates also the problem of «bad housework» («*mauvais mesnage*»), he speaks of the importance of cultivating oneself as to entrust to farmers who try to make the most profit for them and to care of the soil, «without thinking about honor».

He stresses the long term character of activity and importance of care of the natural resources, even if it demands additional costs, by quoting the maxime: « *with work the property is acquired, and with length it is owned: and, it costs more to keep than to buy».* (Olivier de Serres 1651, 47). This kind of approach is similar to historical cost accounting one in accounting for strong sustainability (Hueting 1989; Lamberton 2000; Rambaud and Richard 2015; Murphy and Seabrooke 2019) seeking to take into account all the costs of natural and/or human capitals preservation, instead of evaluating these capitals by market or fair value that is characteristic of accounting for weak sustainability models (McCandless et al. 2008; R3.0).

Olivier de Serres, quoting Caton, called of «great shame to not leave his heritage to his successors greater than had received from his predecessors» (Olivier de Serres 1651, 48-49). This sentence brings to mind a similar definition of accounting for sustainability by Gray (1992, 420):

> a parallel accounting system which provided calculations of what additional costs must be borne by the organisation if the organisational activity were not to leave the planet worse off, i.e. what it would cost at the end of the accounting period to return the planet and biosphere to the point it was at the beginning of the accounting period.

Moreover, Olivier de Serres (1651, 49) notes the importance of soil work «with science and diligence» that could prevent «so many scarcity of all of the kinds». So here too, we see some premises of accounting for strong sustainability in the sense that the last one refers to « safe minimum standard » (SMS) (Ciriacy-Wantrup 1952) and/or critical (natural) capital[3] (Ekins et al. 2003) defined based on scientific norms and eventually collective choices as an aim of conservation.

Finally, concerning the accounting in its more conventional acception, that is measuring and monetary valuation of costs and incomes, Olivier de Serres, even if he acted «with esteem» (Boulaine and Moreau 2002, 77) in cultivating his domain, noted each day each expense in his book of reason. However, he did not encrypt neither his cash receipts, nor the results of its work. But on this point, nobody thought at this time (Boulaine and Moreau 2002, 38). It was only in 1673, long after the first edition of the analysed Olivier de Serres' book, that the first accounting regulations saw the light: Order of March 1673. This order was aiming to stop the bankruptcy and to restore credit (Lemarchand 1993, 101). Among the legal requirements relating to accounting there was an obligation to conduct an inventory every two years.

Remarkably, in 1804, Napoléon supported the reprinting of the Olivier de Serres work, proposed by Society of Agriculture members (Guy, «Histoire de l'agriculture»).

3.2 Mathieu de Dombasle's works and *la Ferme de Roville*

Christophe-Joseph-Alexandre Mathieu de Dombasle (1777-1843), son of a former military Grand Master of Forestry under the Empire, studied chemistry and agronomy; he also worked in the campaign of Luxembourg as an accountant in the service of the convoys. He was a member of the Academy of Sciences, of the Royal and Central Society of Agriculture[4], and of the Society for the encouragement of domestic industry (Lemarchand 1993, 354-355). C.J.A. Mathieu de Dombasle trans-

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[3] Critical natural capital is often defined as the natural capital which is responsible for essential environmental functions and cannot be substituted in the delivery of these functions by manufactured capital (Ekins et al. 2003, 169). Critical natural capital should be preserved whenever possible (Daly 1991).

[4] An outstanding event in the agricultural history of France is the creation of the Royal Agricultural Society of Paris in 1761, preceded by the emergence of regional agricultural societies in some cities (Rennes in 1757, Tours in 1759 and Clermont-Ferrand, Orléans, Rouen and Soissons in 1761). There were mostly nobles (civil servants, lawyers and doctors, rental owners), landowners and some farmers who had land and used it themselves and who applied agronomic theory that was consituted in this period. It is worth noting that these institutions, even being constituted by «agromane aristocracy » and consequently being outside of the peasant masses, were there to encourage the dissemination of technical progress in the countryside (Marache and Bourrigaud 2005).

lated Thaer's and Sinclair's works, the last exponents of classical agronomy in Germany and in England (Argemi 2002). He managed from 1822 and for twenty years the farm of Roville (Roville-devant-Bayon, in the southern department of Meurthe), where he organized the farming school (Knittel 2007). C.J.A. Mathieu de Dombasle was a pioneer of agricultural higher education in France (Boulaine and Moreau 2002). He introduced the cultivation of flax in Lorraine, showed the benefit of lime to improve clay soils, and created a famous plow. Despite his efforts, the cereals yield did not exceed 11 to 12 quintals per hectare.

C.J.A. Mathieu de Dombasle's *Calendar of good farmer or manual of practitioner farmer*, the book edited in 1821 and which had known seven editions from 1824 to 1846, is the first French agricultural manual of double entry bookkeeping (Lemarchand 1993).

In the *Annales de Roville* of 1824, we see that it is from 1823 that the accounting was organized at the farm of Roville, and after their author, it was easy to realize it:

> ... I can assure you that with the exception of the first two or three months, which required me some care to form a *commis* who had no idea of commercial accounting, all is constantly worked with extreme ease. Today everything is always under my direct supervision, and there are even some ledgers, such as tables of rotation, which I reserved for my writing: but such supervision and work demand from me the use of very shortly time. It is this like many things that scare when you see from afar. When once we conceive such accounts, we see that it is extremely simple and does not require much time for writing as one might suppose (Mathieu de Dombasle 1824, 122-23).

Mathieu de Dombasle discusses the usefulness of the auxiliary books, written in the form of tables, where all operations of every day were brought (instead of registering it in the journal, which, in a farm, would form entries to the infinity). Then the results are written in the journal, and from there to the general book, in a single article for each subject at the end of each fortnight.

The author proposes to hold twenty-three auxiliairy books, stressing that «it takes very little time each day to put some numbers on the tables they contain, when the journal is discharged from a multitude of items that it was unnecessary to burden, but it was still very important to keep it» (Mathieu de Dombasle 1824, 116).

For example, the auxiliairy book of livestock consumption was divided into several columns, each of which was devoted to a species of cattle on the farm. Each column is subdivided into other ones, depending of number of forage species, grain or roots they could consume (Appendix 1):

> Every evening one wrotes in this book the consumption of the day, and every two weeks, one registers at the debit of each species of livestock and credit each type of feed, which value it consumed. ... all fodder are bunched, and regularly distributed to men who care each species of livestock… (Mathieu de Dombasle 1824, 117).

Another auxiliairy book, the employees of the farm one, was to receive an indication of the work done every day by teams and farm workers. What is curious is that not only employees, but also horses and working beef had a large column, «divided into a large number of others, who holds the title of special accounts at grand-livre for each species harvested, and other objects that work can be applied to» (Mathieu de Dombasle 1824, 117):

> The unit I have adopted for this table is a work's hour of a man, a horse or a beef. Every evening, one enters the number of hours to be used for each account, which is then debited of the mass of price of all the work it required within a fortnight, in crediting the accounts of employees, of beefs and horses. To this end, I have provisionally estimated at the amount that seemed as close as the truth, is the price that one hour of work a man, a horse, etc. costs; the balance of my accounts then show me if I'm wrong, when tells me so, in a very precise manner, the real price of a work's hour, and therefore the expense that entailed actually every kind of work that I do then use my teams.

Thus, we see that the accounting was held in working hours, in number of quintals of harvest, etc... One could even say that there are already elements of economic analysis and a draft of the standard cost accounting, but also of (management) accounting for sustainability[5] (Schaltegger et al. 2002) because of its tracking and managing the quantities produced and consumed by the farm.

Mathieu de Dombasle described other auxiliary books that were used in the Farm of Roville, including the production and use of manure, the household consumption book with «tables on which one registered every evening: 1° the number of individuals who were fed during the day or at the master's table, or the household table; 2° all items consumed even if they were purchased outside or were taken in the house» (Mathieu de Dombasle 1824, 120). In addition, one of the largest auxiliary books, according to the author, was the the rotation tables one (Appendix 2):

> Every piece of land has its own table, which is divided into as many columns as it contains logs, each log has a serial number. All operations performed in the field, such as plowing, harrowing, use of manure and other fertilizers, sowing, hoeing, harvesting, etc., are entered into the appropriate columns of the table; abreviative signs indicate each operation, and leave little thing to write.
>
> Using these rotation tables, there is not, in the farm, a single ridge of soil, which I will not always have all the information I could wish, to determine me on that kind of harvest it can receive, or to study the results of operations to which it was submitted (Mathieu de Dombasle 1824, 121-22).

Mathieu de Dombasle notes that:

[5] For an example of management accounting for strong sustainability, see Zahm et al. (2019).

> all of these books, which include details of all branches of the farm do not yet constitute a proper accounting; but it has all the elements necessary to establish it with the most accuracy, and these elements are classified so as to commonly require a simple addition, in order to bring them in the journal, where they come to rank back into the grand-livre, which shows the economic performance of each brunch of farm (Mathieu de Dombasle 1824, 122).

In this way we may notice that in 1824, there was an accounting organization similar to that of today. We can also conclude that the main goal of agricultural accounting teeched by Mathieu de Dombasle was to know the economic performance of farm activities.

Indeed, agricultural growth was undeniable in France: between 1815 and 1851 agricultural production increased by 78%, wheat progresses as potato which greatly improves food security. But this growth was achieved by an increase in labor and a declining fallow more than by technical progress (Herment 2017).

Another interesting point in line with accounting for strong sustainability was the issue of depreciation, concerning notably land improvement, which is an expense for the restitution of soil fertility. As noted by Lemarchand (1993, 447-448), in 1826, at the general meeting of shareholders of the Farm of Roville, Mathieu de Dombasle shows have opened a *land improvement expenditure* account debited by expenses of liming, tidal range, removing stones, buildings, «and other operations of the same kind, the effect of which should be felt much time of the lease», and every year a tenth of the total amount will be charged to overhead[6]. These costs are not retrievable; the effects of some of them are necessarily limited in time and any capital gains, thus conferred on soil, go to the lessor at the end of the contract (Lemarchand 1993, 447-48).

These expenses were considered as improving the land, but it was the case from the productivity point of view, and as we know now, not obligatorily aiming at the restoration of natural capital of soil from the actual strong sustainability point of view.

Moreover, Mathieu de Dombasle proposed a distribution system, under a four-year rotation, on the example of a piece of land that once fertilized by manure is successively producing potatoes, barley, clover and finally wheat. The allocation is made by the game of accounts of the various products concerned, from one year to another. The first year, one imputes the full cost of amendment to account of *potatoes*, then at the inventory period credits it by half of this expense by debiting the *barley* account next year. The third year, c*lover* is charged for half of this amount, that is a quarter of the total, but improving itself soil fertility, it is completely discharged at the expense of wheat in fourth campaign[7]. The allocation is as follows: ½ , ¼ , 0, ¼. The mechanism put in place by the agronomist is quite sophisticated,

[6] Rapport à l'A.G. du 28-11-1826, *Annales agricoles de Roville.* 4ème livraison, 1828, p. 47, cited by Lemarchand (1993, 448).

[7] Lemarchand (1993) emphasizes that the same scheme can be found in L.F.G. de Cazaux (1825, 78-80), and A.Malo (1841, 68-70).

it combines the allocation in time and the allocation between productions. The fixed coefficients attempt to reflect actual consumption, in perfect agreement with the prospect of costing (Lemarchand 1993, 448).

It is worth noting that this mechanism is taking into account the clover properties of soil restauration and its necessary presence in the aim of preserving the cultivated soil. So there is a preoccupation, in some kind, for the soil natural capital preservation reflecting actual sustainability point of view.

3.3 Auguste Bella's works and the *Institution royale agronomique de Grignon*

In July 1827, Mathieu de Dombasle's student, Auguste Bella (1777-1856) settled, with Antoine-Rémy Polonceau and Ternau(n)x, the school of Grignon (Seine-et-Oise Region) (Briaune 1837), which later became the National Agronomic Institute of Paris-Grignon (INA-PG, which is actually AgroParisTech). He described the experience of the accounting organization and of the state of the Royal Agronomic Institution of Grignon (*Institution royale agronomique de Grignon*).

The first general balance published in the *Annales de Grignon* dates back to June 1, 1828 and it was signed by Polonceau, the Secretary of the Board, while the following years the status reports were presented by Auguste Bella. Bella also used the double-entry bookkeeping, with the auxiliary books and the Journal. Polonceau in his report has quickly passed under review 13 following auxiliary books: the workforce book, the employees of the firm book, work sheets, books by tables of days and hours employed in the work of carpentry and masonry, the book of instruments manufacture, the one of consumption of straw, fodder, roots, seeds, etc., distributed to each type of animals, the dairy book, the book of household for subordinate employees only, the book specially designed for cows, the manure book, the book of penalties, the book of nominal state of every kind of cattle, and finally, the cash book held in revenue and expenses, day by day.

It should be noted that the auxiliary book devoted to farm workers, that is to say, to the servants and workers of the year, indicated all hours of work and its various specialties. There are also registered, on separate tables, the hours of horses and beef work, always with counting and allocation of hours on specialties, at the supposed prices to make the parity with the cost of these animals. «So the work produced by labor, by employees, horses and beef on the farm, is classified and summarized each day and summarized by a week, a fortnight or a month: everything is then allocated to the various cultures or improvements or other specialties» (Annales de Grignon, 1828, 60). In this way, this method is similar to Mathieu de Dombasle's one.

The accounts were opened to different cultures:

> The first operations, which are defoncemens (sic) or other tillage, are generally represented by potatoes; the following year by cereals, later by alfalfa, clover, leys, etc. One transfers a half of the fertilizer from the first harvest to the second one; thereof half or a quarter of the first to the third harvest. The defoncemens, clearings, extraordinary stone removings resulted in an ac-

> count entitled: Increase in Capital of land for the first extraordinary plowing or clearing work with pick or with shovel (Annales de Grignon, 1828, 65).

One can notice the use of crop rotation, as well as the consideration of soil natural capital of land in accounting to restore by different actions, such as clearings, or extraordinary stone removings, etc., that is one of the features of accounting for strong sustainability.

Moreover, in the Report for the year 1829-1830, Auguste Bella distinguished two types of accounting: that of the farmer that needs «little time for it» and «should be simple and brief», and that of an Institution, «which is accountable to its shareholders and the public of the smallest operations», because «accounting, as all other parts of agronomic science, is perfected by practice and by reasoned application of requirements of localities and of position» (Annales de Grignon, 1828, 105).

Thus, there is an emphasis on distinction between management accounting and general accounting, the last one being dedicated to shareholders and, more generally, to the public use. Like in accounting for strong sustainability, one of which goals is to divulgate an information to different stakeholders, so to different kinds of public, and not only to the shareholders.

Therefore, Bella made several improvements, including the allocation of overhead costs and development of several other accounts, as well as the change of the holding of the grand-livre:

> Every open account gives, besides the value figures, the figures of quantities of each species of food produced or sold. These figures, sorted by columns, present a table where it is easy to see the importance of harvests, of consumption, or of sales (Annales de Grignon, 1828, 105).

It has to be noted, that the importance of taking into account the quantities, and not only the monetary items, for the accounting for sustainability, notably the strong sustainability, is often stressed by researchers (Halberg et al. 2005; Zahm et al. 2008; Richard 2012b; Altukhova 2013).

Finally, Bella notes the advantage of agricultural accounting:

> it attracts attention and has to think about things that have eluded the most careful monitoring. It is to it that the agricultural art had part of his progress in a highly calculating neighboring people. By introducing this system in France, one will make a real service to the country. The government itself will draw, on a range of political economy issues, the lights that in the current state, it can not obtain. So instead of more or less probable calculations of the cost of cereals, ten farmers by department, whose accounts have been accurate, would have given information that it was impossible to get by it [The government]… (Annales de Grignon, 1828, 163).

4. Discussion and conclusion

The socio-historical approach could give us some lessons from the past on accounting for sustainability.

The French agricultural accounting literature was chosen notably because of richness of agricultural accounting literature since the 17th century and of preserved archives of some large experimental farms. But so far, a depth analysis of agricultural accounting has been the subject of few in number research, notably in France (Giraudeau 2017).

One of the first French publications on agricultural management is the Olivier de Serres' book that had 21 editions from 1600 to 1804, and where one can find some premises to accounting for strong sustainability, notably concerning the land measurement, the crop rotation and other techniques for the renewal of soil fertility, as well as the social concerns of decent work and life.

The first accounting practices described by Mathieu de Dombasle, Bella, and many others see their appearance in the tumultuous years just after the Great French Revolution of 1789[8], and develop under Napoléon, and then under *Second Empire* (1852-1880).

As we have seen in the preceding parts, the State was almost always interested in agriculture and its problems, even if the first French ministry in charge of agriculture appeared in 1881.

By the way, the Agricultural Societies were one the favorite instruments of the State in disseminating the knowledge (for example, François de Neufchâteau[9], Minister of the Interior during the *Directoire* period (1795-1799) (there was not yet an economic ministry nor agriculture one), devoted himself to the study and promotion of domestic production, both industrial and agricultural ones (Duby and Wallon 1976, 49).

Later, in 1814, there is the exaltation of the property, the appearance of its various types in agriculture. Large farms were often entrusted to the management of financials, which were not themselves owners or farmers. That is why, the charge and discharge accounting model was often used in seigneurial estates and large farms.

Another interesting fact, from the beginning of 1810s, *Royal and central agriculture society* offered a prize for the redaction of farm accounting treatee (Lemarchand 1993). This interest to the farm accounting may be explained, as we saw *supra*, by the State concern for agricultural production increase and consequently by its en-

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[8] The 1789 revolution is born because the economic crisis was combined in time with the ultimate crisis of the monarchy, financial one, institutional one and moral one (Duby and Wallon 1976, 19-20). Essentially «bourgeois revolution », it coincided with the explosion of a « largely autonomous peasant revolution». The night of August 4, 1789, the abolition of feudalism in all its aspects has occurred.

[9] He might be called the earliest of «agrarians» (if we accept, after Pierre Barral (1968. *Les Agrariens français*, de Méline à Pisani, Armand Colin), to designate by this word in extended meaning, statesmen who thought and acted especially for agriculture). Bourgeois himself, and of innovative spirit (e.g., use of statistical information), François de Neufchâteau wanted to return, beyond the revolutionary turmoil that he also accepted contributions, to the heyday of the Physiocrats, economists, Turgot.

couragement of Agricultural Societies activities. This is perhaps one of the reasons of a very abundant and rich accounting literature destinated to farmers use at this time. This richness, as Lemarchand (1993, 364) notes, even surprised some authors such as Ronald S.Edwards who suggested the existence of a large gap between the prescribed techniques and the practice:

> It would be surprising if agricultural accounting in France at the beginning of the nineteenth century was of the quality described above... In spite of efforts of the early writers, it appears that the farming community of France had not been transformed into a nation of bookkeepers... (Edwards R. 1937, 18-19, cited by Lemarchand 1993, 364).

Indeed, these are mostly large rural estates that are first to introduce agricultural innovations and to practice accounting (Lemarchand 1993; Cocaud 1999). The Domain of Pradel, as well as the Farms of Roville and of Grignon are among them. The last two farms contributed to the industrialization of agriculture, and built the foundation for the French agricultural accounts in double-entry (Lemarchand 1993). So to speak, some books on the farm accounts contain more information than those of industry.

From the writing style and manner of expression of the authors of *Annales de Roville* and *Annales de Grignon*, we can guess that Mathieu de Dombasle and Bella addressed to their farms shareholders and public in general in the reporting and communication aims, but also to farmers in general in the aim of knowledge diffusion.

It has to be noted that the context in which C.J.A. Mathieu de Dombasle and Auguste Bella lived was the first stage of institutionalization of agronomy (between 1750 and 1850) as a new science. Agronomy passed from an « agronomy art » status to that of « agricultural science » (Knittel 2007). The development of agriculture has been situated in a complex reality that was similar to structuration of other sciences, such as geography or medicine.

One could now be led to conclude that one of the main goals of agriculture was the production increase. Indeed, Argemi (2002, 458) points out that «increasing agricultural production was one of the most important means of increasing the wealth of the country». In addition, the main objective of agronomists «was to feed a population that was fast increasing» (Argemi 2002, 458).

However, based on the study of French agricultural management and accounting literature, one could also conclude that, even if the central concern of agronomists was to increase productivity, this passed at sustainability condition!

Accordingly, Kidd (1992, 24) argues that productivity and equity criteria have to be considered in addition to sustainability, «in judging the overall desirability of any system».

Moreover, Mathieu de Dombasle, as well as Auguste Bella show in their accountings the consideration of natural capital of land by opening the accounts of *land improvement expenditure*. There have to be registered the expenses concerning the restitution of soil fertility by different actions, such as manure, clearings, or extraordinary stone removings, etc. This issue of depreciation, concerning notably land improvement, is another interesting point in line with accounting for strong sustainability.

But at the same time, we should not ignore the state of science on the development of physical environmental thresholds to be respected. In the XIXth century, «the scientific principles involved were not well known, but practice had shown increased productivity» (Argemi 2002, 454-55). Jean-Baptiste Boussingault and Justus Liebig also thought that «as many nutrients should be returned to the land as possible» and precised that it has to be done «in the same place where they had been extracted» (Argemi 2002, 459-60).

Thus, in addition to agricultural innovations (such as the use of leguminous crops, improved cultivation and harvesting techniques, new equipement), the French agriculture has benefited from accounting advancements that have taken these first into account.

Indeed, at the Napoléon' time (1802-1814), the dissemination of knowledge, change of agricultural structures made the general increase in living standards. Finally, the *Second Empire* (1852-1880) was a period of a real apogee of peasant France (Duby and Wallon 1976).

So, the meeting between tradition and innovation took place, but farming methods are modified only while agronomic theories are discussed (with creation and development of Royal Agricultural Societies) and while it allows improving efficiency and productivity of the farm.

The authors of studied works are somehow *agromanes* since they gather themselves farmers, agronomists, economists and teachers[10] (Lemarchand 1993). That is the multidisciplinarity feature – the wish of so many accounting for sustainability specialists!

Thus, even four centuries ago, instead of four decades, one can find some premises to accounting for sustainability!

In this regard, we join the relatively recent researches in rural history (Lyautey, Humbert and Bonneuil 2021), in line with science studies and the social and cultural history of science and technology, which consists in historicizing technical choices and scientific rationalities and restoring a multiplicity of knowledge in tension. This is why we describe the socio-economic and political context in which the analyzed works of French authors were developed. Finally, we show that some French authors in agronomy, rural economy and agricultural accounting of XVIIth-early XIXth centuries dealt with ecological and social issues, even if they did not use the word «sustainability». Their ideas may inspire, and somehow explain, the current developments in the accounting for sustainability.

Like Knittel (2007), we can say that the history of agricultural accounting is a field of historiography which calls for a transversal approach combining several disciplines: history, essentially rural one but also history of science and technology, accounting, agronomy, epistemology, philosophy of science and, finally, sociology of

[10] One can enlarge this list of *agromanes* with the Argemi's (2002, 458-59) help. This author cites eminent agronomist who had a scientific background: for example, «Duhamel was responsible for French naval affairs», Chaptal was professor of chemistry and state controller of powder production. «Chaptal ([1823] 1829) advanced toward the identification of agronomy with practical chemistry».

science. After all, the history of agricultural accounting is above all the history of *agromanes*, their work, their discoveries and the institutions in which they worked.

Further research is necessary to deep the conclusions drawn from this study.

As noted by Zimnovitch (2013, 92), «we know how much historical knowledge is beneficial to understand the present time… [but] it is also beneficial to think about the conditions that enable innovations to integrate into the organization».

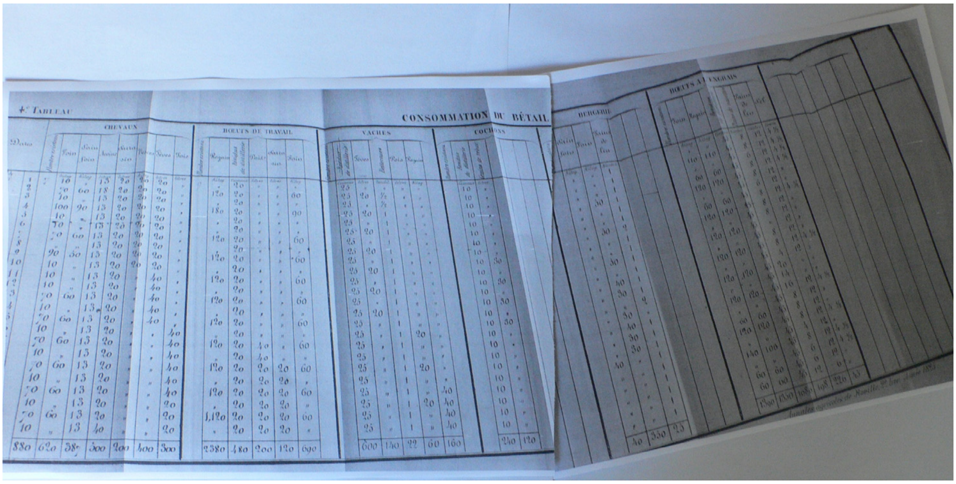
Actually, the limits of this work are particularly associated with the methodological choices made in this research. The methodology adopted is based on the study of three cases and the selected publications of three authors. An originality of the three cases studied is that these farms were experimental and their accounting practices were well documented due to the publications by their managers. So, the problem of generalizing the results may arise, notably at the level of different types of farms with corresponding management differences.

That is why it would be interesting to investigate other French farms archives to see if the developed in De Serres', Mathieu de Dombasle's and Bella's works accounting for sustainability principles were applied effectively (or not, and why?).

Some answers to this question may be found for example in Lemarchand et al. (2017) and Joly (2016b) analyzes.

It would be interesting also to examine the other countries agricultural accounting literature and archives to strengthen our conclusions about the existence of premises to accounting for sustainability. There are mostly historical works on Anglo-saxon agricultural accounting. But note that the Anglo-Saxon accounts do not have the same approach as the accounts in France. In addition, in Anglo-saxon countries the term «sustainability» emerged «in the context of broad social, economic, and political goals, rather than in the context of more narrowly defined resource management and ecological concepts» (Kidd 1992, 18). It would be interesting to see through the accounting theories and practices if it was the case in other countries.

Appendix 1



Appendix 2

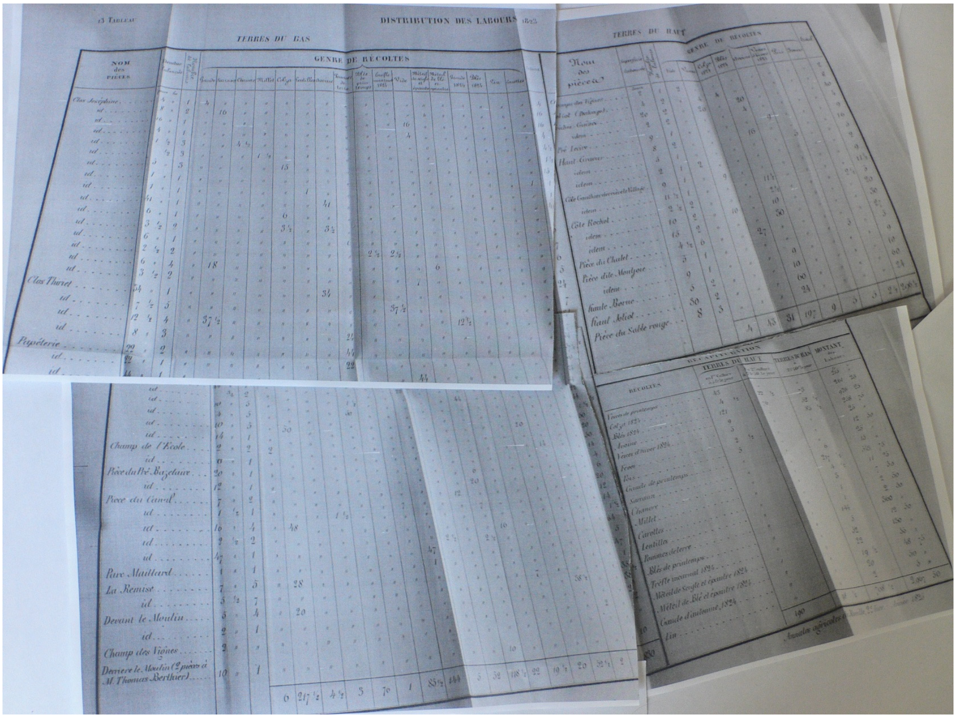


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Tavola rotonda

Round table

Carlos Laliena Corbera

*Useful knowledge, technological innovation and economic development in the European ceramic industries, 14th-18th centuries**

1. Introduction

Despite the evidence to the contrary accumulated by historians, economists such as Joseph Stiglitz and Bruce Greenwald – among many others – continue to argue undaunted that «what distinguishes the modern era of the last two hundred years from the millennia that preceded is *learning*», another way of saying «knowledge» (Stiglitz and Greenwald, 2015, 29). A few years ago, I devoted some time to archaeology and for this reason I feel a predilection for a type of object to which historians pay relatively little attention, despite its unquestionable importance. I am referring to ceramics.[1] For millennia, ceramics have been essential in the domestic sphere and their production has undergone technological and cultural changes whose importance is so obvious that it is not worth pausing to justify it. Like fabrics, ceramics from the thirteenth century presented different modalities: they could be a luxury good or an accessible product, but in both cases, their consumption was very high, with an intense circulation both locally and internationally. The demand was subject to the effects of fashion with a deep cultural background, since the decoration conveyed images, both figurative and abstract, which were representations in the ideological sense of the term. Moreover, ceramics were not subject to reverse engineering. Having a glazed piece did not allow the physical and chemical processes of production to be broken down, and therefore the knowledge transfer necessary to make it had to be carried out by other means, in particular through the displacement of skilled artisans. It is true that ceramics have a limited economic impact compared to other goods, such as textiles, to name the most obvious. Popular ceramics are cheap and luxury ceramics have limited production. However, it is an industry that made the fortunes of some cities and regions and, in

* This paper is part of the research lines of the Group CEMA of the University of Zaragoza, recognized and funded by the Government of Aragon. I thank Julián Ortega for his comments. The assertions and errors, however, are exclusively my own.

[1] The literature on the types of ceramics cited in the text is immense, but it comes almost always from the work of archaeologists or art historians. In the latter case, it is mostly from collection and museum or exhibition catalogs and tends to be very repetitive. The citations, therefore, are a very personal reading guide, but, in general, they contain additional bibliography that includes the classic works. In addition, the reader can easily find images of the ceramics discussed in the text on the Internet, which allows them to be omitted in this publication.

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Referee List (DOI 10.36253/fup_referee_list)
FUP Best Practice in Scholarly Publishing (DOI 10.36253/fup_best_practice)
Carlos Laliena Corbera, *Useful knowledge, technological innovation and economic development in the European ceramic industries, 14th-18th centuries*, © Author(s), CC BY 4.0, DOI 10.36253/979-12-215-0092-9.25, in Giampiero Nigro (edited by), *L'economia della conoscenza: innovazione, produttività e crescita economica nei secoli XIII-XVIII / The knowledge economy: innovation, productivity and economic growth, 13th to 18th century*, pp. 419-429, 2023, published by Firenze University Press, ISBN 979-12-215-0092-9, DOI 10.36253/979-12-215-0092-9

general, it was a product of high consumption and complex production that, in addition, is hardly recorded in the general summaries of technological development.[2]

My aim is to show in a very concise way how the production of European glazed ceramics underwent three phases of intense transformation of useful knowledge related to its production, with a successive accumulation leading to increasingly efficient results and a higher level of productivity. Moreover, it can be safely stated that, without this accumulation, the progress of the 19th century in this area would have been impossible.[3]

2. *Green and brown ceramics* and the *archaic majolica*

The first of these rapid increases in creativity and dissemination of ceramic production techniques took place during the 13th century throughout the Mediterranean. Between 1200 and 1250, the technical solutions needed to glaze ceramics, which were known in various parts of the Muslim world,[4] were transferred to the Christian areas. In about thirty years, ceramics of this type were produced in Marseille, Barcelona, Valencia, Teruel, Pisa and Genoa, that is, throughout the western Mediterranean (*Vert et brun* 1995; Marchesi, Thiriot, Vallauri and Leenjardt 1997; Beltrán de Heredia 2007; Martí 1998; Ortega 2002; Berti and Gelichi 1995). In summary, the technological change consisted of the fact that the table ceramics were made by means of a double firing, the first to form the piece and the second to fix the decoration. This was done by painting with copper and manganese oxides and a solution of lead and tin oxides for vitrification, which give the name to this type of ceramic, «green and brown». Tin was fundamental because it made the background opaque and highlighted the ornaments. In the 14th century, cobalt blue was also introduced to increase the range of colours. The result was an affordable and colourful product, two qualities that ensured its commercialization and that fall within the chapter of «luxury of the poor». However, the same tableware, with heraldic or aristocratic motifs, was used at the tables of the urban nobles and patricians. The price was less important than the distinction derived from the chromatic richness, the images and even the personalization of these table services.[5] It is nec-

[2] For example, Mokyr only mentions Josiah Wedgwood's experiments in the 18th century to produce porcelain (Mokyr 2002, 52; 100).

[3] I will leave aside the common pottery, unglazed, undecorated or with simple decorations, intended for cooking and storage. It should be noted that many of these problems have been dealt with in the *Atti dei Convegni Internazionali della Ceramica del Centro Ligure per la Storia della Ceramica* (Albisola, Savona).

[4] During the second half of the 9th century, formulas for firing, vitrifying and decorating ceramic pieces were developed in Iraq, which were accorded a high symbolic content in the aulic circles. In the Islamic West, these techniques were known from the beginning of the 10th century and were widely spread throughout the Maghreb, the Iberian Peninsula and southern Italy: Watson 2004; Bernus-Taylor 1995; Coll 2014; Coll and Salinas 2021.

[5] Valencian artisans of the 15th century described the quality of the pieces alluding to social hierarchies: *obra de papa*, *obra de emperador*, *obra real* (pieces decorated in gold and blue). The ceramics of *obra de pinzell* were painted only in blue, while those called *obra de contrafeyt* were painted in green and brown: López Elum 2005.

essary, in any case, not to minimize the complexity of the procedures, which included the use of different types of clays, innovative ovens, very controlled firing temperatures, optimal use of metal products, decorative skill and knowledge of the tastes of demand (Berti, Gelichi and Mannoni 1997; Coll 2014, 73-89; Caroscio 2009, 41-48).

Entire towns, such as Teruel, Manises or Paterna, to mention only the Spanish ones, concentrated their industrial activity in the production of enormous quantities of these ceramics, which soon began the path towards an increasing technical sophistication, an increasing variety in ornamentation and extensive commercialization (García Porras 2009). This type of high-consumption cheap ceramics continued to be produced until modern times in Italy under the designation of «archaic majolica» in Faenza (Emilia), Montelupo (Tuscany), Orvieto and Deruta (Umbria), where production sometimes adopted formulas characteristic of rural industries (Berti 1984; Caroscio 2009, 51-112). Between the 15th and 16th centuries, the growing urban demand made the workshops carry out an increasingly standardized production in shapes and decorative motifs. In addition, they were reorganized to include an internal division of labour and to increase speed and productivity. It is also possible to observe the grouping of workshops under a single owner or an entrepreneur who marketed the production, for example, in Tuscany (Caroscio 2009, 40-41). Both Valencian and central Italian ceramics spread in northern Europe where they have been found in hundreds of archaeological sites (Blake 2021; Gerrard, Gutierrez and Vince 1995). Finally, the rise of glazed ceramics must be measured by the gradual replacement during the 14th century of wooden or metal bowls and cups by the corresponding objects in this type of ceramics, as well as by the incorporation of sauce boats and large plates for the presentation of food on the table. From the end of the following century, the individual plate was slowly introduced and, with it, new forms of consumption of ceramics, which, in the Italian case, were mainly *ingobbiata* ceramics (the cover of the piece was made by a coating of a type of clay different from that which formed the body). This evolution in the use of table ceramics is much later in the northern areas of Europe (Caroscio 2009, 153-59).

It is important to note that in northern Europe varnished ceramics were produced, these were pieces with a transparent glass overlay that showed the background colour of the clay and therefore offered a much lower visual quality than the Mediterranean ones. Until the early sixteenth century in the Netherlands and until the second half of that century in Great Britain, potters did not obtain the appropriate knowledge to manufacture glazed ceramics, which indicates the difficulty of transmitting very specific industrial know-how. In fact, the vehicle for disseminating these techniques was the emigration of Italian artisans to the Netherlands and, later, of Flemish potters to Britain, fleeing from war and religious conflicts (Poole 1995; Goffin 2012; Veeckman *et al.* 2002).

3. *Gold-lustre ceramics* and *Renaissance majolica*

Throughout the 14th century, the Muslim workshops in Malaga and Granada perfected the formula for producing «gold-lustre» or «metallic» ceramics, which significantly modified the chemical components of the decorations and introduced a third firing, to obtain brilliant pieces characterized by combinations of gold and gold and blue on white. As it is easy to suppose, this technical innovation required an even more sophisticated knowledge of the physicochemical properties of ceramics and even more complex and prolonged learning processes. By the end of that century, the Valencian artisans of Paterna and Manises were already in a position to execute pieces of this high quality and flood the European market with their products, in which they were dominant until the end of the 15th century (García Porras, 2006; Coll, 2008). The emergence of this new body of technical knowledge led to the separation of high-end ceramics and aristocratic consumers and the most popular ceramics. The first concentrated the sequence of technical and ornamental transformations that we are going to examine, while the lower-level ones continued to use the traditional technical and cultural repertoire, while incorporating new colours and a wide catalogue of shapes and decorations. The success of these gold reflecting ceramics in Italy was particularly noteworthy, since they surpassed in attractiveness the archaic majolica that had not managed to evolve sufficiently to meet the demands of the elites (Spallanzani, 2006; Orlandi, 2019: 571-572). The emergence in the Mediterranean area of ceramics that are often called «de Málaga» or «Hispanic-Moorish», regardless of where they would have been manufactured, is the beginning of the second great phase of technical and cultural creativity to which I have referred.

The hegemony of Iberian ceramics was broken around 1500, when the knowledge necessary to manufacture these productions of gold lustre was disseminated in the Italian centres. During the first decades of the 16th century, Italian ceramics gradually took over the European luxury and semi-luxury market.[6] On the basis of the previous findings both in the preparation of the pigments and in the firing systems, the *Renaissance* majolica adopted an extraordinarily rich expressive language, both for the complexity of the more or less abstract ornaments and for the figurative designs, with representations typical of the painting of the time. [7] The success of these ceramics can be measured by the multiplication of the production centres, the specialization of each of them in shapes, colours and decorative aspects, as well as by their export to all Europe and America.[8] The example of Faen-

[6] However, still in 1581 *piatti alacatalana de Deruta* and *piatti alacatalana romaneschi* («Catalan dishes from Deruta» and «Roman Catalan dishes») were sold in Rome, indicating the prestige that Valencian productions (here, qualified as «Catalan») still retained (Pesante, 2019: 58).

[7] The variety of decorations serves to classify these maiolicas into groups: those called *istoriato* for including narrative scenes, *grotesques* for using motifs derived from the findings of the Neronian *Domus Aurea*, and *porcelains*, for imitating the details of Chinese porcelains that were beginning to arrive in Europe (Syson 2016).

[8] The literature is dominated by catalogs of large museum collections: *Maiolica* 2016; Hess 1988; Thorton and Wilson 2009; Wilson 2017, among many others. For a study of the origins of these centers: Caroscio 2010. A synthesis on maiolica: Wilson 2007.

za, which gave its name to glazed ceramics in English or French, is very significant, but it is not unique: Deruta, Perugia, Urbino and Montelupo are other places where this industry flourished. Many of the surviving pieces are genuine works of art and are listed in the catalogues of the property of 16th-century princes. But the interesting thing about these ceramics is that their value was not as considerable as that of other precious objects and they had a demand that was not restricted exclusively to the upper classes. Price calculations suggest that top-quality ceramics were ten times more expensive than majolica, which was not an unbearable cost for relatively large layers of the population. This implies that marketing remained large on a social and geographical scale.

However, the technical difficulties resulting from the third firing were the cause that high range production was only 10% of the total output of the ovens, judging by the archaeological findings in places such as Cafaggiolo (Caroscio 2010, 99). On the other hand, the circulation of artisans in Italy and outside the peninsula meant that technical knowledge was already far from being a secret at the beginning of the 17th century and multiplied the production centres. Finally, the commercialization favoured mutual influences and imitations between the different areas of ceramic manufacturing, at least in the decorative aspect.

The adoption by Italian potters of the techniques of enamel and gold lustre originating in the Iberian Peninsula marked the beginning of an expansive movement of these productions on a European scale during the early modern age. Therefore, it is reasonable to state that the first feature that characterizes this second phase of the industrial development of glazed ceramics is the loss of Mediterranean exclusivity in the technological knowledge necessary to produce them. From the beginning of the 16th century, the dissemination of Italian technical knowledge passed to France and the Netherlands and reached Great Britain and other regions of the north and northeast of the continent from the following century.[9]

Secondly, ceramics ceased to be only a functional element such as tableware to acquire a huge variety of uses. In particular, the beauty of the large plates and vases commissioned by the aristocratic elites made them objects of artistic exhibition. However, it is not easy to distinguish when these magnificent pieces were also used in sumptuous activities. Orders of complete tableware sets suggest that they often continued to have practical value. In addition, the artistic intention caused the morphologies of the pieces to multiply to include not only practical objects, but also a very wide series of small ornamental sculptures.[10] This obviously implies an uninterrupted sequence of technical progress, in which we find all kinds of forms of knowledge transfer, from industrial espionage to the circulation of artisans.

Finally, it is necessary to emphasize the economic aspect of the manufacture of ceramics in this period. Undoubtedly, raw materials were affordable and, at least

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[9] During the 16th century, several Italian craftsmen specialized in the manufacture of maiolica pottery settled in Lyon and Nevers: Rosen 2021: chap. 4 and 5. In the second half of the 17th century, under the impulse of Colbert and a general increase in the demand for ceramics, the production sites of *faïences* multiplied: Rosen 2021: chap. 6. From 1550, Italian master potters were documented in Delft and other cities in the Low Countries and the production of glazed ceramics began.

[10] I have deliberately left out the use of glaze on tiles, which, however, was one of the important sectors of ceramic activity, since it would involve a problem as wide-ranging as the one discussed here.

since 1450, the skill of painting specialists accounted for most of the final cost of the pieces. As with other items in the pre-industrial era, low artisan pay and accessibility did not preclude considerable buyer interest and significant appreciation for the quality they achieved. However, it is necessary to avoid an exclusively aesthetic perspective of ceramics. Low prices are not synonymous with subsidiary value in the area of the productive economy. On the contrary, as Richard Goldthwaite has shown, the Italian centres had real entrepreneurs, both merchants and master potters. The classic example of Faenza suggests that we should pay attention to the massive increase in production in Italian cities and semi-urban centres and, later, as in Delft, in northern Europe.[11] On the other hand, the expansion of majolica must be seen in the context of the increase in the capacity of European societies to consume since the late middle ages, as evidenced by recent historiography, both in economic and cultural history.

4. The age of porcelain

At the same time that Renaissance majolica was triumphant, Chinese porcelain arrived in Europe in increasing numbers, both from Portuguese factories in the East and through the Manila galleon via America. They were immensely appreciated ceramics from several centuries before and their presence in the market caused the third major technological upheaval to which I have referred.

Chinese ceramics were significantly different from European ceramics in their technical processes – in particular, firing – but, above all, because of their essential raw material, kaolin. Without this component, the whiteness, the blue decoration, the rigidity, the nuances of brightness and transparency, in a word, the sensuality of the porcelain, was unattainable to Western potters. That doesn't mean they didn't try to emulate them. From the second quarter of the sixteenth century, Italian artisans sought to reproduce Chinese porcelain through majolica, with appreciable results only in the decorative field. It was the beginning of a major technological effort at European level to supply a market that demanded porcelain or imitations at all costs. The evidence that Chinese ceramics were of a higher technological level – and manifested a production of global dimensions – led Europeans to buy huge quantities of porcelain. It is not worth insisting on the obsessive collecting of some kings and princes of this period, but it is worth noting that porcelain was transformed into a global commodity with a very large cultural impact (Krahe 2016; Weststeijn 2014). The proof is that wealthy Europeans asked Chinese artisans to copy the typologies of typical Dutch, Venetian or French objects and even to adapt the decorations to the Western taste, with narrative and heraldic motifs (Finlay 2010).

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[11] Goldthwaite (1989, 14) also insists that the economic importance of ceramics should not be overestimated, but the indications of archaeologists are decisive in showing the enormous demand that existed for glazed ceramics. Glazed ceramics are found in all excavated sites of a chronology after the 15th century. A concrete example of the economic importance of pottery on a regional level: Musgrave 1997.

European imitations failed in strict terms, as no porcelain equivalent to Chinese porcelain was produced until the 19th century. But this failure was relative because under a state or private inspiration the third great phase of technical innovation took place with the appearance of the potteries of Delft, Lisbon and Talavera (Van Dam 2004; Lahaussois, Dumortier, Bierboer and Van Dam 2008; Lahaussois 1998; Seseña 1989; Frothingam 1944). A stage that culminated with those of Sèvres, Meissen and the ceramics of Josiah Wedgwood in England already in the middle of the 18th century (Walcha 1975; Brunet and Préaud 1978). As in previous phases, these productions combined medium-range ceramics with true works of art of exquisite level. In any case, they all contributed to meeting a very high demand. By way of example, Delft pottery in the 18th century gave the name – *delftware* – to all the pseudo-porcelain that circulated in Britain regardless of its place of production.

I will take as an example of the economic importance of the ceramic industry at this time the Alcora factory in Valencia, founded in 1727 and directed with an extraordinary personal effort by the Count of Aranda, the greatest politician of the Hispanic monarchy of the Enlightenment (Peris 1996; Coll 2009; *El esplendor* 1995). The declared objectives –besides generally strengthening Spanish industrialization– were twofold: to make porcelain and to supply the Hispanic market.[12] This second part was achieved: the annual average of pieces that came out of the Alcora furnaces was around 220,000, with a maximum between 1752 and 1763, years in which 4 million pieces were produced. At the height of production, more than 300 workers worked in the facilities, of whom a quarter were apprentices. There were schools in the factory where specialists were taught drawing and painting. Six ovens were used to cook the pieces in the different stages of production.[13] Some more were added for the so-called «*pipe clay*» and for the «soft-paste» porcelain, variants that were not real porcelain but that were as close as they could get with the raw materials available. The marketing included Italy, France and Hispanic America, but the distribution took place mainly in the Spanish territory through an extensive system of shops and factories.

The Count of Aranda failed to obtain authentic porcelain, but it was not for lack of initiative, since he hired French and German experts on several occasions to apply the appropriate chemical formulas, but the lack of kaolin could never be overcome. Despite this, Alcora's ceramics sustained the comparison both in quality and in decorative richness and adaptation to the tastes of the time with the great European factories, at least until 1800, when the war and the disappearance of the American empire definitively weighed down this experiment of enlightenment.

5. Conclusion

This journey through the medieval and modern history of ceramics clearly shows that over these centuries there has been an exceptional accumulation of use-

[12] In 1727 it is stated that they intended to manufacture ceramics «in the manner of China, Holland and other localities» (Coll 2009, 177).

[13] The two largest kilns could produce between 25,000 and 30,000 pieces. There were 12 potter's wheels working continously.

ful knowledge about the properties of clays, the chemical components of decoration, the effects of heat and the forms of ornamental representation, through very active phases of experimentation. The circulation of this knowledge led to forms of hybridization of such peculiar products as European Chinese imitation porcelain or Chinese ceramics with western decorative motifs. The transmission of this knowledge includes all possibilities, from the traditional teaching of masters to apprentices to the displacement of specialized artisans and, of course, espionage, not to mention the actions of a state nature to promote these prestigious productions. It is important to underline the notion of «prestige», since raw materials, with a few exceptions, were not expensive and what really made ceramics expensive was the work of painters and decorators. However, only select or custom-made pieces constituted true luxury items, although they are the ones that have survived best. Much of the production was oriented towards markets with a certain purchasing power and in which there was a strong demand for social distinction. Ceramics is part of the development of a modern consumer society, together with silk and cotton fabrics, tea or chocolate, and, consequently, was subject to the imperatives of fashion. This explains the enormous and ever-increasing proliferation of different forms of these objects. The catalogue of Alcora, around 1750, had 300 different models, and in the rest of European industries the phenomenon was similar, at least since the sixteenth century.

Technical knowledge, demand and intense commercialization in the first stage of globalization promoted productivity growth, which should be examined on a case-by-case basis, production centre by production centre, something that is yet to be done, since ceramics are usually studied by art historians and not by economic historians. But in all the phases of development that I have pointed out, processes of specialization or division of labour, economies of scale and standardization took place, the latter even with greatly expanded repertoires. Therefore, it seems to me impossible to deny that productivity grew in each of these cycles and with it a mass production. Other factors, such as differences in quality and management from workshops and craft corporations in terms of target market strata, should be examined. But I will content myself with insisting that the enormous development of the medieval and modern ceramic industry would have been impossible without high technical knowledge in the framework of a pre-industrial knowledge economy.

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Markus A. Denzel

Round Table comment:
From «useful knowledge» to a «culture of growth»

It is a very great honour and pleasure for me to present some ideas at this round table and to such a group of excellent scholars who have been experts in the topic of our *Settimana* long before I began to engage in this field of research. So, I only can try to deliver insight in some of my impressions I have got during this very inspiring Settimana, but it would not be possible to summarize all the well-prepared and ingenious papers presented to us in the last three and a half days. First of all, let me stress that from my point of view it was an excellent *Settimana* with such a broad variety of aspects of knowledge economy in pre- and early industrial times, whereby the term 'knowledge economy' (cf. Rooney et al. 2005) can be defined – according to Joel Mokyr (2002)[1] – «as one that produces sufficient 'useful' knowledge to generate a process of modern economic growth». It has been our aim to reflect on how knowledge facilitated economic growth before 1750 to 1820 by the improvement of productivity and by resilience[2] of European medieval and modern societies after subsequent demographic, economic, and war crises. In preparation of this *Settimana* three key terms were identified, «useful knowledge», innovation, and productivity. These key terms were the main subjects of the three working days, after Carlos Laliena Corbera had held his very inspiring *Prolusione* on the general topic on Sunday afternoon.

Before the conference, scholars have pointed to the substantial transformations that occurred in useful knowledge in the late medieval and early modern period, but in assessing the impact of these transformations on economic growth, they have tended to highlight institutional and social contexts more strongly than technological innovations. It was the aim of our *Settimana* to – let me say – 'modify' this a little bit and to shift the focus (again) to the economic aspects, at least to the same degree as recent research has emphasized cultural ones. From my point of view, this is a very important thought, because we dealt with economic knowledge!

So, I would like to point out that we should speak about useful economic knowledge or economically useful knowledge – not only simple useful knowledge. Most of the knowledge compiled by humankind was useful – I guess –, but was it

[1] Of course, not all ideas and arguments of Mokyr's idealistic approach are accepted for granted in the scientific community, and quite a body of criticism was expressed in some of the reviews, which, however, concern more single details than his main arguments (cf. Mokyr et al. 2004).

[2] In our context, "resilience" indicates «recovery capacity» and «development on a new basis» in the field of economy.

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Referee List (DOI 10.36253/fup_referee_list)
FUP Best Practice in Scholarly Publishing (DOI 10.36253/fup_best_practice)

Markus Denzel, *Round Table comment: From «useful knowledge» to a «culture of growth»*, © Author(s), CC BY 4.0, DOI 10.36253/979-12-215-0092-9.26, in Giampiero Nigro (edited by), *L'economia della conoscenza: innovazione, produttività e crescita economica nei secoli XIII-XVIII / The knowledge economy: innovation, productivity and economic growth,13th to 18th century*, pp. 431-434, 2023, published by Firenze University Press, ISBN 979-12-215-0092-9, DOI 10.36253/979-12-215-0092-9

economically useful as well? This differentiation is very important from my point of view, and especially for the appraisal of the results of our conference. We heard only one contribution concerning the economic knowledge on agriculture, peasantry and all features of rural economy (Yulia Altukhova-Nys), which covered up to 90 percent of the pre-industrial economic output and which was – in the scope of the so-called Agricultural Revolution – the most discussed and described economic field at least in 18th century England (Overton 1996; Allan 2000), perhaps in France and the Holy Roman Empire as well. Most of the pre-industrial technical skills constituted a fine background for innovations in crafts and industries since the Middle Ages (e.g. von Stromer 1977), and in the commercial activities the elaborate techniques of bookkeeping and costing became more and more essential instruments for crises and resilience management (cf. Denzel 2020) of commercial and later industrial enterprises. So, I think that economic historians should concentrate more on these economic factors than on the cultural ones. If we ask for the best basic parameters of economic growth, economic factors are decisive, and cultural factors take only the second or an even lower rank.

After these preliminary remarks, I would like to present some impressions of this fifty-third *Settimana*: First of all, I am impressed by the variety of sources we heard about, from the craftsmen's texts (Julia Bruch) to the tally sticks (Tanja Skambraks) as well as the Saxonian price competitions (Seiji Horii). These are only some examples. I guess that most of us did not have such sources in their focus when they thought of knowledge economy. Nevertheless, these sources give us excellent information in theory and practice and bring the material culture close to the classic economic history, and this can and will enrich our further research.

The speech of Bert De Munck who emphasised that the reputation of craftsmen went down when information on their crafts were published in a broader manner, made me pensive. His finding is quite correct when I think about the situation in the Holy Roman Empire in Early Modern Times. But it is the other way round, when we look at merchants and businessmen: Their reputation in society was strengthened as information on their profession was published in the merchants' handbooks of the 16th and 17th centuries and the famous encyclopedias of the 18th century. From the point of this question of research I would like to suggest that we should widen our perspective into the 19th century, because in the wake of the industrialisation many new institutions of practical education were founded, from the *Gewerbeschulen* up to the technical universities in Germany. The German lands and later the German Empire were leading in the latter sector followed by Austria, the United States with the MIT and Switzerland with the ETH. And the graduates of these institutions have enjoyed a very high reputation by their societies, which modifies the argument we have discussed in the long term. But this was outside of our focus, and therefore we concentrated on the dissemination of useful knowledge by classic universities and the crafts' apprenticeship system (Carlos Fernando Teixeira Alves; Maarten Prak and Patrick Wallis).

These two last-mentioned scholars made an almost perfect transition to the second day stressing that innovation may be interpreted as a result of improvement in human capital. All kinds of innovations enriched the economically useful knowledge, albeit in different manners and to varying degrees. We learned about military innovation (Fabrizio Antonio Ansani), about technical procedures (Måns Jansson and Göran Rydén), and we gained a detailed insight in the English putting-out system (Nicholas Amor). In contrast to this focus on crafts and pre-industrial industry (the Germans have some issues with these terms), three papers on Monday and Tuesday presented innovations in the scope of commerce concentrated on bookkeeping (Heinrich Lang; Markus A. Denzel), and the role of the Hindu-Arabic numerals in this regard (Raffaele Danna). Goran Proot, Renaud Milazzo, and Andrea Ottone put the book at the centre of their contributions as the perhaps most important medium of early modern communication and useful knowledge transfer, as well as the book markets and the basics and strategies of book production.

The third day's papers confirmed Joel Mokyr's statement that «technological creativity blossomed in fifteenth-century Europe» (Mokyr 2016, 143), but no medieval Industrial Revolution in the full sense of this term took place (cf. Gimpel 1975; von Stromer 1980s). Didier Boisseuil showed us such technological creativity in his case study about the new alum production in Western Europe, and Louis Sicking demonstrated it by means of the spritsail and its effects on maritime transport and commerce. But not only such creativity boosted the productivity in a specific part of the entire economy, but also financial literacy could do this as Sandra De la Torre Gonzalo discussed in her case study on late medieval Aragón. Such useful knowledge – be it financial, technological or about markets – could contribute to a higher productivity and, in the last consequence, to economic growth. This became obviously clear in the outstanding speech of Richard W. Unger, who linked closely progress in naval technology over centuries to global economic growth, concluding: «The shipping sector offered … sources of growth and resilience of the economy». Last, but not least, Yulia Altukhova-Nys combined profitability with sustainability by using the example of agricultural accounting in mercantilistic France. This is it for a short survey of our Settimana so far!

Although one might assume that the variety of themes presented in our conference has been too broad, I would not agree. Only this wide spectrum of detailed insights in production, commerce, finance and agriculture gives us the possibility to answer the questions we expressed in our Call for Papers – at least partly. It is neither the time nor the place to answer all these questions here in detail, but I think that we can state that economically useful knowledge could induce innovations which further deepened and widened this economically useful knowledge; and this cycle was at least one of the decisive factors of raising profitability and, as a final consequence, of economic growth becoming obvious in the industrial evolutions in different European and later also non-European countries. To say it more clearly: Innovations did influence economic growth. Cultural and institutional processes, which generated knowledge and human capital, could influence the development of labour productivity. Knowledge did contribute to reduce risks in pre-industrial societies through information, communication, and resilience. But one question remains open: To what extent was the «culture of growth», which Mokyr (2016) has postulated for the Early Modern European economy, based on a specific European knowledge economy? And this question could be a starting point for further discussions and research.

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Richard W. Unger

Round Table comment

In the papers given here there is frequent mention of «useful knowledge». It is always informative to ask what the opposite of any idea or object might be. In this case useless knowledge does, in fact, exist. The question that follows, then, is useless to whom and why. Useful knowledge it would seem is connected to increases in productivity and, in turn, to economic growth. Ideas always abound. Many theories are available with ideas often shared widely. In only certain cases, though, do those ideas that knowledge is useful, yielding the desired economic results. Concentration on knowledge turns the spotlight away from the importance of the practical, the role of the market in dictating what, under the circumstances, makes implementation of certain technologies that spring from knowledge practical and beneficial and others not. In short, the existing circumstances dictate what is useful knowledge. The adoption of new technologies is never straightforward since, whatever that way of doing things may be, new entanglements, spillovers, cross-fertilization create unintended consequences which of course then dictate what new technologies will in turn gain acceptance or, in other words, what knowledge will be useful.

In the past historians trying to understand how and why ways of doing things changed distinguished invention and innovation. They also sought to divide technical from technological change. The loss of those distinctions is not necessarily bad. Still it is wrong to ignore such separations since what drives novelty on the one hand and what drives the implementation of new methods are different. Renaissance thinkers made much of 'creation', of the role of the artist in making something that was new. The idea was most prominent in the discussion of individual painters, sculptors and architects thanks to the work of Giorgio Vasari (1511-1574) and the subsequent promotion of the approach by art historians. The evidence is overwhelming that it takes more than just a creative person or spirit to invent. Simultaneous invention occurs. Since two people chose to work on the same problem at the same time in different places with no contact with each other have produced the same solution there must be more than individual creativity at work. The most notable case is the Hall-Héroult process for producing aluminium, developed independently by two men in France and the United States in the 1880s. Creation of some new technology is not enough to make for universal adoption. No matter how creative the inventor and invention, there are typically some who resist accepting the brilliant new idea, even long after the new practice is in common use. Those resisters are not invariably wrong to resist.

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Referee List (DOI 10.36253/fup_referee_list)
FUP Best Practice in Scholarly Publishing (DOI 10.36253/fup_best_practice)
Richard W. Unger, *Round Table comment*, © Author(s), CC BY 4.0, DOI 10.36253/979-12-215-0092-9.27, in Giampiero Nigro (edited by), *L'economia della conoscenza: innovazione, produttività e crescita economica nei secoli XIII-XVIII / The knowledge economy: innovation, productivity and economic growth,13th to 18th century*, pp. 435-437, 2023, published by Firenze University Press, ISBN 979-12-215-0092-9, DOI 10.36253/979-12-215-0092-9

There may well be a curiosity among people to explore new ways of working and producing and that curiosity may be more or less widespread at different times. But what may be true generally is not what generates the observed specific technical changes and their diffusion. The discussion of knowledge transfer, something that permeates much of the discussion, is certainly of value. Knowledge transfer, however, is not technology transfer. For the latter there must be much more than just knowledge moving.

An invention can prove to be a massive breakthrough, creating an entirely different economy. It can be a simple change a craftsman made. It can be anything in between. The are big ideas, and there are not so big ideas and very much lesser ideas or practices. In order to understand the roots of specific inventions, no matter their impact or source, the starting point should be well before the specific invention emerges. The big ideas do count and they include how inventors and innovators understood nature. For the history of European technology that means that exploring the history of technology requires knowing about Aristotle or even Plato or even Hesiod. While beginning with the big picture to understand the small is advisable that does not denigrate working from small ideas, from highly circumscribed information to uncover explanations for major breakthroughs. Exemplarism of Aristotelians and most prominently in the middle ages, an idea strongly endorsed by Thomas Aquinas (1225-1274), promoted data collection, learning about nature to see God's handiwork. That thinking and practice could and did lead to technological change. Along with gathering knowledge the work of craftsmen had value in the eyes of theologians in the middle ages. Hugh of St Victor (c.1096-1141) in his *Didascalicon* of the 1130s adds to the list of the arts, that is the seven subjects of the quadrivium and trivium, a list of the mechanical arts. Woodworking might not have been exactly as important as geometry, for example, but certainly it was worthy of praise. The monastic religious culture of the middle ages did not ignore technicians and their work. It is wrong to disregard the medieval background to the strides made in technology in Europe in later centuries. It is easy to make too much of some altered consciousness which suddenly created the urge to invent in the sixteenth or seventeenth or any later century. Perhaps it is wise to see that urge as something less time-specific and more a common feature of the human condition. That was a logical outcome of the views of Adam Smith (1723-1790) who assumed that people are both lazy and competitive and so inventive.

The role of public authorities, institutions that could engender as well as administer technological change, in putting knowledge to use is an enigma and for no other reason than the sheer variety of what they did. They had the potential to promote or thwart technical advance. Government authority geographically could cover large areas of land or just regions or just towns. Administratively it is easy, looking back, to imbue states with powers they only gained in later centuries. Considering their limited powers in the years before 1800, it is wise to be sceptical of what appears in the documentation they produced. The laws laid down frequently were not enforced. The establishment or extension of territorial states in northern Europe from 1400 on was not so revolutionary since they were modeled on city states in Italy but their effective rule was constrained by the sheer size of the realms they claimed. Cities could and did, through guilds for example, have a greater role than territorial states in the creation and dissemination of new technologies. However, there was always a tension between cities and tradesmen. They shared some interests but also had what could be diametrically opposed goals.

Technology transfer might better be understood as adoption or adaptation of some different way of working. Transfer, by definition, means that the technology already exists. Transfer, then, is not original. That was and is why there is a distinction made between invention and innovation. The distinction implies that discussion of technical change must include existing social and cultural and market conditions. It also implies a need to understand the old technology undermined by the new. What is novel must be similar to what already exists to be acceptable. For example, with printed books, their creation being a major breakthrough in Europe at the end of the middle ages, producers went to great lengths to make them look like manuscripts. More generally, the importance of standardization in the adoption of a technology is often understated. It was not just machines like the Jacquard loom which produced a predictable, that is standard, product, that made both production and acceptance of the product easier. Music notation in the eighteenth century became more consistent so that musicians with little or no knowledge of a piece could play it in groups, understanding from the printed page what was needed of them. Like the original manuscript book, the codex that emerged in the last days of the Roman Empire, the printed book became standardized in size. Booksellers' catalogues could describe an easily understood commodity. Written works appeared from the fifteenth century on that served to establish categories and so make possible useful instructions. Medieval cookbooks served as models for how-to books but written works came to cover many more topics, in all cases moving slowly toward standardization of categories, of ways of describing and even of ways of illustrating technologies. Those works were a product of technical change and at the same time a way to ease the transfer of knowledge and of technology.

Trying to comprehend and then to describe the process of technological change and its impact is a difficult task. Explaining it is then extremely demanding. Many of the contributions in the papers offered indicate the value of thick description, of looking closely at relevant documentation, piecing together events from those documents and presenting the information in a comprehensible way. Placing that description within the context of time and place, making the small picture part of the big picture is, after all, doing good history.

Abstract[1]

YULIA ALTUKHOVA-NYS, Productivity? – Yes, but subject to sustainability! An evidence of (re)emergence of accounting for sustainability from the French agricultural authors from the XVIIth to the beginning of the XIXth centuries

Five decades ago, first works and researches that have as title or subject « Environmental accounting », « Ecological accounting », or « Social accounting » have emerged. In these works, there are notably examples of accounting for strong sustainability approach in the agricultural sector. This paper searches for accounting for sustainability premise in the French agricultural accounting literature of XVII-beginning of XIX centuries. It demonstrates that this literature presented some strong sustainability issues, although as a productivity and innovation diffusion condition, even earlier that the term of «accounting for sustainability» existed.

NICHOLAS R. AMOR, The origins of the putting-out or domestic system of industrial production in England

The putting-out system of production was a key feature of England's woollen cloth industry and is regarded by many historians as a step along the road to capitalism. This paper considers the evolution of the industry in the late Middle Ages, the emergence of clothiers and their dependent out-workers and the nature of the relationship between the two groups. A detailed analysis follows of the growth, between 1475 and 1510, in the value of textile related debt litigation in the Court of Common Pleas, and revised estimates are given for the scale of the industry and the size of the workforce in the early-sixteenth century. Thus an assessment can be made of the importance of the putting-out system and its contribution to the success of the textile industry at that time.

[1] In questa sezione del volume abbiamo inserito gli abstracts inviatici dagli Autori.

FUP Best Practice in Scholarly Publishing (DOI 10.36253/fup_best_practice)
Giampiero Nigro (edited by), *L'economia della conoscenza: innovazione, produttività e crescita economica nei secoli XIII-XVIII / The knowledge economy: innovation, productivity and economic growth,13th to 18th century*, © 2023 Author(s), CC BY 4.0, published by Firenze University Press, ISBN 979-12-215-0092-9, DOI 10.36253/979-12-215-0092-9

FABRIZIO ANTONIO ANSANI, Le conseguenze economiche dell'innovazione bellica. La produzione di «artiglierie alla francese» a Firenze tra Quattro e Cinquecento

Il saggio mira a valutare l'impatto economico della rapida assimilazione delle artiglierie «alla francese» nella tattica italiana, concentrandosi in particolar modo sulle misure adottate dalla Repubblica Fiorentina per incrementare l'efficienza del proprio apparato logistico durante i primi anni della Guerra di Pisa (1494-1509). Attraverso uno studio rigoroso delle fonti contabili, la ricerca metterà in risalto i considerevoli cambiamenti intervenuti in un settore strategico dell'economia pubblica, restituendo la giusta importanza a merci scarsamente considerate dalla storiografia contemporanea ed evidenziando il significativo impulso dato dai governi rinascimentali alla costituzione di uno dei primi monopoli di stato, quale, appunto, l'industria quattrocentesca delle «munizioni».

The paper aims to assess the financial impact of the rapid assimilation of the French-style artillery into Italian warfare. The focus will be on the policy adopted by the Florentine Republic to improve the efficiency of its logistic system during the War of Pisa (1494-1509): through the analysis of public records, the research will highlight the significant transformations occurred in late medieval military industry, reevaluating the importance of the trade in strategic materials for the early modern economy and demonstrating the concerted effort made by the rising renaissance state to establish a monopoly on the manufacture of arms and «munitions».

DIDIER BOISSEUIL, La production d'alun en Occident: l'essor d'une industrie nouvelle à la fin du XV^{e} siècle

Cet article se propose d'explorer les conditions dans lesquelles la production d'alun s'est déployée dans le monde méditerranéen occidental, au cours de la seconde moitié du XV^{e} siècle. En deux décennies, entre 1460 et 1480 environ, plusieurs sites de production importants sont apparus dans la péninsule italienne ou dans la péninsule ibérique. Ils ont fourni aux industries et l'artisanat européen un alun de qualité et ont éclipsé rapidement les sources d'approvisionnements qui avaient jusqu'alors prévalu en Anatolie ou de la Mer Égée. L'article évoque les connaissances utiles mobilisées pour faciliter cet essor, notamment les techniques mises en œuvre et les acteurs de ce basculement.

This article explores the conditions under which alum production has developed in the Western Mediterranean, in the second half of the fifteenth century. In two decades, between about 1460 and 1480, several important production sites have appeared in the Italian peninsula or in the Iberian peninsula. They have provided European industries and crafts with quality alum, and they quickly overshadowed sources of supply, that had previously prevailed in Anatolia or the Aegean Sea. The article discusses the useful knowledge mobilized to facilitate this growth, in particular, the techniques used and the players involved in this changeover.

JULIA BRUCH, Transmission of useful knowledge in texts written by craftsmen. Two case studies from the Holy Roman Empire

In medieval and early modern crafts, useful knowledge was taught in the workshops. There, innovation took place. Craftsmen exchanged knowledge on journeys or through voluntary and forced migration. This system of knowledge transfer does not need writing, although craftsmen used writing both in the workshop and in the administration of the guilds and the towns. However, transmission of knowledge remained oral. This contrasts with countless craftsmen's manuscripts that conveyed technical knowledge about crafts in text and images. This essay argues that these manuals were equally crucial for the transmission of useful knowledge between master craftsmen as well as the sale of products to clients. A book on plate harnesses and one on bell and gun casting are introduced as examples.

RAFFAELE DANNA, The spread of Hindu-Arabic numerals among practitioners in Italy and England (13^{th}-16^{th} c.): two moments of a European innovation cycle?

Together with introducing a set of key innovations in commercial practices, the merchant-bankers of the commercial revolution of the 13^{th} century were also the first European economic agents to adopt Hindu-Arabic numerals. As practical arithmetic provided the mathematical foundation for commercial innovations, studying its European spread provides a particularly suitable angle to study the diffusion of practical knowledge in the pre-modern period. Italy was the early adopter of these techniques, while in England these practices became widespread at the onset of the little divergence. In this paper, I discuss in comparative perspective the social diffusion of this knowledge in Italy and England, and its wider impact. On the one hand, this analysis makes it possible to show a number of parallels between the trajectories followed by these societies. On the other hand, it allows to observe the complex interactions between practical knowledge and wider economic, institutional, and social changes.

MARKUS A. DENZEL, Bookkeeping as a 'key technology' of pre-modern commerce. Its relevance for the economic development in Europe

It is the aim of this paper to analyse the importance of (double-entry) bookkeeping for the economic development in Europe and its possible indirect influence on economic growth. Being one of the most important commercial techniques of the European merchants double-entry bookkeeping stayed in close relationship to the expansion of trade. So, the distribution of different bookkeeping techniques all over Western and Central Europe, took place, on one hand, through the extensive commercial contacts of Italian merchant-bankers with merchants of regions north of the Alps and because of the need of many non-Italian merchants to consolidate their commercial knowledge in Italy through specific studies and/or through acquiring practical knowledge. On the other, treaties on (double-entry) bookkeeping supported its diffusion. The study analyses examples of ledgers as 'mirrors' of their enterprises' activities, and it will be shown how such ledgers served as instruments for reducing various risks of entrepreneurial engagement. As a result it will become clear that the knowledge of the technique of double-entry bookkeeping was one of the preconditions of the commercial and, later on, the industrial expansion of the Europeans, which made a significant difference to other merchant cultures in the world.

Questa presentazione mette in risalto l'importanza della contabilità in generale e la partita doppia in particolare nel contesto dello sviluppo dell'economia europea e la sua influenza sulla crescita economica. La partita doppia era una tecnica essenziale nell'ambito commerciale dei mercanti banchieri, ed aveva quindi un rapporto fondamentale con l'espansione del commercio. Perciò la diffusione delle diverse tecniche contabili in Europa occidentale e centrale si svolse attraverso i contatti intensi tra i mercanti banchieri italiani e quelli delle regioni al nord delle Alpi e a causa del bisogno di mercanti non italiani di consolidare la loro conoscenza commerciale in Italia con studi specifici o imparando praticamente. I manuali di contabilità e di partita doppia contribuirono a questa diffusione. Questo studio analizza esempi di libri mastri come "specchi" dell'attività di impresa e intende mostrare come essi funzionarono come strumenti per la riduzione di rari tipi di rischio. Ne risulterà che la conoscenza delle tecniche della contabilità e la partita doppia fu un prerequisito dell'espansione del commercio e, di seguito, dell'industria europea, e costituì una differenza essenziale con le altre culture mercantili nel mondo.

SEIJI HORII, Promotion of high-quality textiles by prize competitions during the Enlightenment in Saxony. From raw material to finished product manufacturing

Preisaufgabe, or «prize competitions» were implemented in Saxony in 1764 to promote industry after the Seven Years' War. We investigated the purpose of them and by whom, by analysing primary historical texts to uncover four criteria: (1) the best quality prototypes; (2) equivalent quality to foreign products; (3) establishment of training facilities, and (4) manufacture of new products. The competitions promoted high-quality products and disseminated knowledge. Numerous prototypes were submitted and prizes awarded. Most participants were already engaged in textile or related industries and the strategy relied on this intellectual foundation. Assessment of Saxony's situation and enlightenment principles informed the competitions.

MÅNS JANSSON, GÖRAN RYDÉN, The œconomia of iron and steel. Material transformations, manual skills, and technical improvementin early modern Sweden

Sweden was a major exporter of iron during the early-modern period, but there was also an important domestic steelmaking. We analyse the Swedish iron and steel trade in a long perspective in a European context. Our approach departs from recent discussions on industrial and scientific developments, in which the spheres of «Hand» and «Mind» are brought together, and where artisanal skills and natural resources are highlighted. We emphasise how the migration of people, and movements of materials and knowledge, influenced a process of gradual change. A key feature was the ongoing interactions between working people and educated *savants*. Our conclusion points to the perseverance of artisanal skills well into the nineteenth century, but also towards new links between work, technology, and markets.

CARLOS LALIENA CORBERA, The knowledge economy in the preindustrial era

The aim of this paper is to verify that in economies prior to the 18th century and from the Middle Ages onwards, there was a significant increase in the application of knowledge in the goods produced and a development of both technological and organizational innovation, i.e. «useful knowledge». It is also a question of verifying the effect of cultures, institutions and power structures on the generation of knowledge, its diffusion and its technological and productive use. In conclusion, the reduction of risk and the increase of productivity were aspects linked to the "knowledge economy" also in the pre-industrial era.

CARLOS LALIENA CORBERA, Useful knowledge, technological innovation and economic development in the European ceramic industries, 14th-18th centuries

Ceramics have been essential in the domestic sphere and their production has undergone in the preindustrial era technological and cultural changes whose importance is obvious. This paper is to show in a very concise way how the production of European glazed ceramics underwent three phases of intense transformation of useful knowledge related to its production, with a successive accumulation leading to increasingly efficient results and a higher level of productivity. Moreover, it can be safely stated that, without this accumulation, the great progress of the 19th century in this area would have been impossible.

HEINRICH LANG, «Li vostri che tenghono li libri non sanno tenere tanti chonnti». Useful knowledge and accounting as seen through the accountant's lenses and the logic of capitalism

Knowledge of accounting before the evolution of academic economic knowledge was practical knowledge. In the context of the studies about the development of accounting techniques, the debates leave out the bookkeeper. The hypothesis here is that, due to the diversification of investments on the behalf of the personal properties in late fifteenth and early sixteenth centuries, an expert accountant appeared as bookkeeper of the personal account books at the merchant bankers' households. In Florence, future merchants were trained in elementary schools and later on in classes the masters of abacus. In their exercise books, the masters of abacus published, we find a lot of algebraic problems which are illustrated by accounting operations. However, at least in Florence manuals on accounting did not exist. So, the young merchant bankers and bookkeepers learned by doing. A case study about an accountant, Matteo Brandolini, who was the bookkeeper of the papal banker's son Alamanno Salviati, shall exemplify this tendency. When the patricians and merchant bankers invested more extensively in secondary markets, they were in the need of highly qualified staff.

ANDREA OTTONE, Market assessment and risk prediction: resources and know-how of a seventeenth-century bookseller of Venice coping with competition

This article explores the likelihood that early modern printers had developed rudimentary practices aimed at assessing their market of refer-ence to pursue strategic commercial planning. It surreys the inner evidence of a single manuscript bibliographic compiled by a minor mem-ber of the Giunta publishing house active in Venice in order to propose the hypothesis that said catalogue may have been instrumental to commercial bibliometrics aimed to avoid harmful competition between redundant editions within the same market area.

MAARTEN PRAK, PATRICK WALLIS, Transferring useful knowledge. Quality mechanisms in European apprenticeship

Human capital is central to current debates about the sources of growth and divergence in the premodern economy. Apprenticeship, the key formal arrangement by which occupational skills were transferred in this period, has in the past often been associated with guild monopolies and exclusion, implying a drag on the accumulation of human capital. Several stimulating recent contributions have pointed to apprenticeship as a potentially important explanation for English or European advances in manufacturing and technology in the run up to industrialisation. In this paper, we explore mechanisms that helped improve quality among artisans. We focus on one in particular: the selection of training masters by apprentices.

JORAN PROOT, The economic revolution in book design that went unnoticed: changing paper thickness in folios, quartos and octavos. The case of the Southern Netherlands, 1473-c. 1550

This contribution discusses the evolution of paper thickness of books produced in the Southern Netherlands in the period 1473 until the middle of the sixteenth century. Changing paper thickness is one of the key elements which in all likelihood helped coping with the problem of the rapidly increasing demand for paper by the press. After a description of relevant aspects of the production of hand laid paper and of the resulting morphology of sheets, a methodology is proposed to deal with the problem of establishing paper thickness in bound volumes and further problems dealing with the compression effect and of binding and rebinding are discussed.

TANJA SKAMBRAKS, Tally sticks as media of knowledge in the contexts of medieval economic and administrative history

Tally sticks worked as ubiquitous stores of numerical knowledge and tools of accounting and administration in medieval Europe. Previous research emphasized both the potential and value of the wooden notched sticks not only for the social and economic history of the middle ages, but also for the history of writing, intellectual history. This article combines the analysis of archival objects and written sources from England and Germany analysing their various contexts of use. These involve the centralised, highly professional and ritualised tax accounting at the English Exchequer, husbandry and agriculture, consumer taxation as well as public credit and circulating money-substitutes. Furthermore tallies were often used as evidence in court and functioned alongside written administration.

CARLOS FERNANDO TEIXEIRA ALVES, Knowledge, economy, and university in the south of Europe at the end of the eighteenth century. The case of Salamanca and Coimbra

In this paper, we will try to analyze the reforms of philosophy curricula at the Universities of Salamanca and Coimbra, and their connection to the economic development of their respective economies. We will demonstrate how this reform altered curricular contents with the purpose of guaranteeing a formation that could potentiate a better exploitation of the natural resources, mainly of their colonies. In this logic, the most emblematic disciplines were natural history, botany and chemistry. However, factors external to these educational reforms demonstrated their limits. We speak of a lack of jobs for philosophers (and mathematicians), but also a decline in national economies.

SANDRA DE LA TORRE GONZALO, Management and governance of the kingdom's finances. Financial literacy as useful knowledge in late-medieval Aragon (1365-1515)

This paper's primary research question is to what extent change in mechanisms and instruments of financial management proceeding from trading knowledge improved the efficiency of late-medieval poli-ties. To do so, we have examined a territorial state experience in medie-val Iberia. In the mid-14th century, Aragon designed its autonomous fiscal system managed by a kingdom's finance. The new supra-local pol-ity made use of financial accounts to keep track of revenues and to ac-cess credit, which led to the refinement of documentary practice and monitoring methods. The analysis brings up the agency of a group of merchants that shaped the functioning of the Aragonese treasury from budgeting to tax collecting. Particular attention is paid to the impact of the increasing prominence of financial numeracy on institutional ac-countability and governance.

RICHARD W. UNGER, Ships, shipping, technological change and global economic growth, 1400-1800

The major breakthrough in ship design around 1400 creating the full-rigged ship constituted a general purpose technology. It had far-reaching effects on shipping, trade volume, orientation of trade routes, location of production, settlement patterns and many other aspects of life throughout the globe from 1400 to1800. The greater efficiency of the type in a number of uses led to its dissemination, to a limited degree, throughout the world. Spillovers from the success of the design were extensive and included for example a literature on designing and building ships, improvements in navigation and in government practices. Advances in shipbuilding were one of the very few technologies in the period that qualified as a technological advance with massive consequences.

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THE KNOWLEDGE ECONOMY: INNOVATION, PRODUCTIVITY AND ECONOMIC GROWTH, 13TH TO 18TH CENTURY

The studies presented here analyze the relationship between the knowledge economy and innovations, productivity, and economic growth in the premodern period (13th-18th centuries) by considering the following questions: how was "useful knowledge" transmitted between individuals, across space, and across generations? How could commercial and industrial productivity have been associated with the expansion of such knowledge? When and where was useful knowledge concentrated in such a way that a relatively large number of innovations and inventions could cause revolutionary breakthroughs in particular sectors of the economy?

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ISBN 979-12-215-0091-2 (Print)
ISBN 979-12-215-0092-9 (PDF)
ISBN 979-12-215-0093-6 (XML)
DOI 10.36253/979-12-215-0092-9
www.fupress.com