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MIRAGRODEP Dual-Dual (MIRAGRODEP -DD) with an application to the EU-Southern African Development Community (SADC) Economic Partnership Agreement (EPA)

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Table of Contents

Abstract

MIRAGRODEP Dual-Dual is a recursive-dynamic multi-region, multi-sector computable general equilibrium model, devoted to trade and agricultural policy analysis. It is developed for AGRODEP and draws upon the MIRAGE model built by CEPII. It incorporates specific features of African economies. In addition to the usual dichotomy between rural and urban activities, it also features the distinction between formal and informal activities (double dualism a la Stifel-Thorbecke). The model includes other features such as foreign direct investment and runs with a tariff aggregation module that allows the user to capture the exclusion effects at a detailed level and the variance of tariffs. The model also includes a submodule allowing to test different closures for the public sector as well as the inefficiency of the tax collection system. Social Accounting Matrix (SAM) and trade data in MIRAGRODEP are based on the GTAP database. Additional sources such as MacMap are used for protection data.

1. Introduction

This Technical Paper is aimed at presenting a new version of the MIRAGRODEP model. This new version includes modelling of rural-urban migration in African countries along with modelling of the reallocation of unskilled labor between formal and informal sectors in these economies. We call this version the Dual-Dual version of MIRAGRODEP (or MIRAGRODEP-DD) since it studies how economic activity evolves between rural-formal, rural-informal, urban-formal and urban-informal sectors in African countries. This new version of MIRAGRODEP also includes better modelling of fiscal revenues in these countries.

We test this new version of MIRAGRODEP by studying the impact of the Economic Partnership Agreement between the SADC region and the European Union.

Why MIRAGRODEP-DD? Most of classical CGE studies in international trade work with simple sets of assumptions about the labor market that are not appropriate to developing countries, and in particular Sub-Saharan countries. Our new version of MIRAGRODEP first makes a distinction between workers attached to the rural versus the urban sector, second takes into account mobility between formal and informal sectors because productivity and wages differentials imply different effects of trade policies on the structure by sector of economic activity. In particular we adopt modelling that is inspired by Stifel and Thorbecke (2003)[1], but we design it in order to match our sectoral decomposition (sectors allocated into formal/informal and urban/rural ones).

The topic of fiscal revenue is a key issue in these trade negotiations. Consequently, a specific modelling effort was undertaken to gauge the impact of the trade agreement on public revenues, in particular to account for existing fiscal inefficiency and to move from nominal duties to actual revenues. The approach here prioritizes the "Consistent Aggregator Approach" for import tariffs.[2] This approach allows us to capture the exclusion effects at a detailed level and the variance of tariffs.

The MIRAGRODEP-DD model is presented in Section 2. Section 3 presents the results of the modelling scenario. Section 4 proceeds to a sensitivity analysis. Section 5 concludes.

2. The Model

We now present the general features of the model on which this evaluation is based. Annex 1 includes a complete technical presentation of the model.

[1] See also Bouët, Dienesch and Fall (2013).
[2] See Laborde, Martin and van der Mensbrugghe (2011).

2.1 MIRAGRODEP

MIRAGRODEP is a Computable General Equilibrium (CGE) model based on MIRAGE (Modelling International Relations Under Applied General Equilibrium). It is a recursive dynamic, multi-region, multi-sector model. MIRAGE was initially developed at CEPII and is devoted to trade policy analysis.

As opposed to a single country CGE model, a multi-country CGE model allows for a detailed and consistent representation of the economic and trade relations with the rest of the world. International economic linkages are captured through the international trade of goods and foreign direct investment (FDI). A dynamic version of the model is achieved by solving the model sequentially and moving the equilibrium from one year to another. In our study we assume perfect competition in all sectors which enables us to have a detailed geographic and sector decomposition.

In MIRAGRODEP, the government is explicitly modelled as a different agent from the private agent. The income of the government consists of taxes collected on production, on factors of production, on exports, on imports, on consumption, and on households' income. The government is supposed to maximize a Cobb-Douglas utility function: government spending on each commodity is a fixed share, in value, of total public expenditure in goods and services. Government purchases are subject to taxes. The Consistent Tariff Aggregator approach has been implemented in MIRAGRODEP. This is an important element of the modelling since the project will be conducted at a relatively low level of sector disaggregation (37 sectors) while in terms of import tariffs, it is often stated that the devil is in the details. The Consistent Tariff Aggregator approach allows to take into account the variance of tariffs at the tariff line level.

Social Accounting Matrix (SAM) and trade data in MIRAGRODEP is based on GTAP 9 (Narayanan and Walmsley, 2012). The GTAP Data Base is a fully documented global data base which contains complete bilateral trade information, transport and protection linkages among 130 regions for all 57 GTAP commodities for 2011.

MIRAGRODEP has already been used to study issues related to international trade and trade policy in Africa. Bouët, Deason and Laborde (2014), in particular, study the potential evolution of international trade in Africa, depending on various trade liberalization scenarios, either regional or multilateral.

There are three important assumptions of the model: they are the external account closure, the government account closure, and the private account closure.

The latter assumption concerns the savings-investment closure. MIRAGRODEP is neo-classical: the marginal propensity to save is constant such that variation in income leads to variation in savings which brings to variations in investment.

The external account closure concerns the assumption on the current account (the current account includes exports and imports of goods and services, plus public and private transfers from or to the rest of the world).

In MIRAGRODEP it is assumed that the real exchange is affected by the reform in such a way that the current account balance is constant (in the model expressed as a percentage of global GDP).

The other important assumption is the government or public account closure. It concerns how the public balance is affected when taxes are changed by a reform. In MIRAGRODEP it is assumed that the public deficit/surplus is constant. In this case, when one source of revenue for the public agent is reduced (import tariffs in this study), there is another component that needs to be adjusted in order to maintain the constant level of public deficit/surplus. For this illustrative example, it is assumed that after a shock that reduces custom duties, public expenses adjust such that the public sold is constant.[3]

2.2 Specific features for this study

In order to mode the Southern African economies better, our CGE model framework was modified in the representation of the labor market in order to reflect a "dual-dual economy". This expression is borrowed from Stifel and Thorbecke (2003). It refers to the double dichotomy between urban and rural areas and formal and informal sectors. Indeed, many of the classical CGE studies in international trade work with simple sets of assumptions about the labor market that are not appropriate to developing countries, assuming especially fixed or uniform labor supply. Thus, to address this, our CGE model presents a mechanism which endogenizes labor supply and a labor-market segmentation which is based on a distinction between unskilled and skilled workers but also between rural and urban activities. As underlined by Stifel and Thorbecke (2003), two main features can help to conceive the idea of dualism: first, the existence of strong inequalities between rural and urban regions, in terms of localization of the activities and in second place the dichotomy between traditional technologies, in which most of firms are family-owned, and modern technologies hold by more complex organizations. This double dichotomy between sectors leads to classification of sectors into four categories: rural sectors are divided into formal (exporting agriculture, with capital-intensive technology) and informal sectors (subsistence agriculture), and urban sectors, into formal (mainly manufacturing) or informal (services). The MIRAGRODEP model is also simulated with traditional assumptions concerning the labor markets in order to evaluate how these new assumptions change our understanding of the impact of trade liberalization.

Let us now present the equations in detail.

In the developing countries on which this study focuses, i.e., Mozambique, Botswana, South Africa, Namibia and the region "rest of SACU", informal sectors have been selected after a review of literature[4] and after consideration of the importance of capital and skilled labor in all sectors since informal sectors

[3] The user can also assume that it is a tax which is increased in compensation of lost public revenues on import tariffs. For instance a lumpsum tax (constant tax by person) can be perceived such that the real public expenses per capita are constant and the public balance is constant.

[4] See Benjamin and Mbaye (2012) and de Vreyer and Roubaud (2013).

are not supposed to hire skilled labor and are supposed not to be relatively capitalistic. In these 5 countries/regions there are 13 (thirteen) informal sectors: vegetables and fruits, oilseeds, other crops, Construction, Cereals, Sugar, Cattle, Other Animal, Fisheries, Red Meat, White Meat, Dairy products, and Trade. In those countries of interest, formal sectors are the other sectors not in the 13 mentioned above.

In these 5 African countries, skilled workers are only employed in formal sectors but within formal sectors they may decide to migrate to urban or rural sectors. Skilled workers get better salaries in urban areas. There may be several explanations of this prevailing gap. One is that everything else being equal, there is a preference for living in rural areas. Another one is the existence of a monopolistic union which determines urban wages of skilled workers in formal urban sectors by maximization of its utility which depends on the number of the union's members and the level of salary given to its members: this results in a salary higher than the one that would prevail without a monopolistic union. Consequently, four equations determine the levels of wages and employment for skilled labor in countries with Dual-Dual modelling. If r is a country with Dual-Dual modelling we have:

$$WHu_{r,t} = WHr_{r,t}(1 + gap_{h_r}) \quad (1)$$

$$Hu_{r,t} + Hr_{r,t} = \bar{H}_{r,t} \quad (2)$$

$$Hu_{r,t} = \sum_{i \in urban(i,r)} H_{i,r} \quad (3)$$

$$Hr_{r,t} = \sum_{i \in rural(i,r)} H_{i,r} \quad (4)$$

With

$WHu_{r,t}$ the remuneration of skilled labor in urban sectors in country r at time t;

$WHr_{r,t}$ the remuneration of skilled labor in rural sectors in country r at time t;

$gap_{h_r}$is a constant positive parameter;

$Hu_{r,t}$is the total demand for skilled labor in urban sectors in country r at time t;

$Hr_{r,t}$is the total demand for skilled labor in rural sectors in country r at time t;

$\bar{H}_{r,t}$ is the total supply of skilled labor in country r at time t.

For unskilled workers, wages are lower in informal sectors than in formal sectors. There are different explanations of this gap: minimum wages, transaction costs, higher productivity in formal sectors due to capital intensive process of production. According to which of these are urban or rural sectors, this gap may differ. The mobility of unskilled labor between rural and urban areas is determined by an equation of migration: migration stops when the salary in formal rural sectors, $WLr\_formal_{r,t}$ is equal to the expected salary that can be obtained in urban areas where either an unskilled worker works in urban formal sector

(probability $\text{Prob\_Lu\_formal}_{r,t}$ and gets a salary of $WLu\_formal_{r,t}$, or he works in a urban informal sector (probability $1 - \text{Prob\_Lu\_formal}_{r,t}$) and gets a salary of $WLu\_informal_{r,t}$. This probability is a function of the share of the urban formal employment of unskilled labor $\text{Lu\_formal}_{r.t}$ in total employment of unskilled labor in urban sectors: $Lu_{r,t}$. Consequently there are eleven equations describing this double segmentation of the employment of unskilled labor in countries with dual-dual modelling:

$$WLr\_formal_{r,t} = Prob\_Lu\_formal_{r,t} WLu\_formal_{r,t} + [1 - Prob\_Lu\_formal_{r,t}] WLu\_informal_{r,t} \quad (5)$$

$$Prob\_Lu\_formal_{r,t} = cp_r \frac{Lu\_formal_{r.t}}{Lu\_informal_{r.t} + Lu\_formal_{r,t}} \quad (6)$$

$$Lu_{r,t} + Lr_{r,t} = \bar{L}_{r,t} \quad (7)$$

$$Lu\_formal_{r,t} + Lu\_informal_{r.t} = Lu_{r,t} \quad (8)$$

$$Lr\_formal_{r,t} + Lr\_informal_{r.t} = Lr_{r,t} \quad (9)$$

$$Lu\_formal_{r,t} = \sum_{formal(i,r)} Lu_{i.r,t} \quad (10)$$

$$Lu\_informal_{r,t} = \sum_{informal(i,r)} Lu_{i.r,t} \quad (11)$$

$$Lr\_formal_{r,t} = \sum_{formal(i,r)} Lr_{i.r,t} \quad (12)$$

$$Lr\_informal_{r,t} = \sum_{informal(i,r)} Lr_{i.r,t} \quad (13)$$

$$WLu\_formal_{r,t} = WLu\_informal_{r,t}(1 + \delta u_r) \quad (14)$$

$$WLr\_formal_{r,t} = WLr\_informal_{r,t}(1 + \delta r_r) \quad (15)$$

With:

cp_r a positive constant;

$\text{Lu\_informal}_{r.t}$: urban informal employment of unskilled labor;

$Lr_{r,t}$: total employment of unskilled labor in rural sectors;

$\text{Lu\_informal}_{r,t}$: total demand for unskilled labor in urban informal sectors in country r at time t;

$\text{Lu\_formal}_{r,t}$: total demand for unskilled labor in urban formal sectors in country r at time t;

$\text{Lr\_informal}_{r,t}$: total demand for unskilled labor in rural informal sectors in country r at time t;

$\text{Lr\_formal}_{r,t}$: total demand for unskilled labor in rural formal sectors in country r at time t;

$WLr\_informal_{r,t}$: the remuneration of unskilled labor in rural informal sectors in country r at time t;

δu_r: a positive constant;

δr_r: a positive constant.

2.2.1 Data

The MIRAGRODEP model is mainly built upon the GTAP database. We will rely on the GTAP 9 database which is the latest version available at the time of writing. The database contains the social accounting matrices for four SADC countries (Botswana, Mozambique, Namibia, and South Africa). Lesotho and Swaziland are aggregated in a region called Rest of SACU (RSACU).

The model is based on a geographical and sectoral disaggregation that includes 15 regions and 35 sectors. The lists of these regions and sectors are presented in Annex 2 and Annex 3, with correspondences to GTAP regions and sectors. Amongst the 35 sectors, there are 14 agricultural and food sectors and 2 primary non-agricultural sectors. Amongst the 15 regions, there are five countries or regions from SADC and three regions from Africa and not from SADC: ECOWAS, Middle East and North Africa region called MENA, and the rest of Africa called RAFRICA.

2.3 Baseline and Scenario

The policy scenario is well defined in the recently signed agreement by both parties, however it is useful to clarify several elements.

First, regarding the baseline in terms of market access, starting from a 2012 database, it involves:

- EU GSP reform starting on January 2014;
- Other EPA signed with third countries (in particular the one signed with West Africa) and specific preferences granted to Central American countries.

This new baseline is used as a benchmark to measure the market access concessions granted by both parties. These concessions are implemented at the HS6 level using the consistent aggregator approach, considering the exact liberalization schedule with the proper dynamics and exceptions.

We implement all the changes on an 8-digit basis, using a new tariff database, based on TARIC for the European Union where we have both the partner and the regime information. We consider that either the ACP regime or the intermediate EPA regime is removed; the best second option in terms of tariff level is kept. To aggregate tariffs, we use the methodology developed by Laborde, Martin, and Van der Mensbrugghe (2011), called the consistent aggregator. This is the only methodology that allows us to consistently combine the right welfare and tariff revenue outcomes.

Therefore, compared to the base-year, two simulations are performed:

- The Baseline;

- A Market Access Scenario: the market access component of the EPA;

Since we adopt new modelling consisting of a representation of the rural-urban mobility and of the labor reallocation between formal and informal sectors (dual-dual model), we also conduct sensitivity analysis of the same policy scenarios without the dual-dual assumptions in order to see if these assumptions significantly modify the results. This will be done in section 4.

3. Results

We first present how the implementation of the EPA modifies protection at the border, then we evaluate how these changes in protection affect exports and imports of the main countries and their public revenues. Then we turn to production at the sector level and remuneration of productive factors. We then evaluate how this reform changes the allocation of labor in SADC countries between rural and urban sectors, but also formal and informal sectors. Finally, we provide estimations concerning macroeconomic variables like GDP and welfare of the representative agent.

3.1 How is market access changed by the reform

The reform has a minor impact on global protection and global access to markets. This is shown on Table 1 and Table 2 on the following pages. Both tables present protection applied on total imports of goods (i.e., the average degree of protectionism – services are excluded) and protection faced on all exports (i.e., the access to foreign markets) from 2012 until 2035. The 'B' column (B for Baseline) presents average duty when no policy reform is implemented while the 'S' column (S for Scenario) presents average duty when the policy reform is implemented.

We do not adopt bilateral imports in the product affected by the protection as weights to calculate an average duty applied on imports or an average duty faced by exports since these are endogenous weights: bilateral imports directly depend on tariffs such that the higher the tariff the lower the imports are. With a tariff so high that it prohibits imports, weight would be zero. Consequently for average duty applied on imports, for average duty faced by exports as well as for average duty applied by s on products coming from r (bilateral protection) we weigh a tariff imposed by country s on product i coming from country r by imports of product i by country s from all countries in the world.

The average protection applied by the European Union on goods, already low in the baseline (0.89% in 2012 and in 2035), is only marginally affected by the reform (minus 4 bp in 2035).

SADC countries implement a reduction of import duties on products coming from the European Union on a limited range of goods, such that the decrease in average protection is almost not significant: from 7.04% to 6.96% for Mozambique in 2035, implying a reduction by only 8 basis points (bp) of average protection for this country; from 3.55% to 3.52% for South Africa in 2035 (a reduction by only 3 bp of average

protection); from 3.50% to 3.48% for Namibia in 2035 (a reduction by only 3 bp of average protection). For Botswana and the Rest of SACU, it is close to 0.

Table 1: Protection applied on all imports from all origins – 2012/2035 – Baseline -Scenario

	2012			**2035**		
	B	**S**	**Variation**	**B**	**S**	**Variation**
Rest of the World	2.68%	2.68%	0.00%	2.68%	2.68%	0.00%
Asia	4.04%	4.04%	0.00%	4.04%	4.04%	0.00%
North America Free Trade Area	3.23%	3.23%	0.00%	3.23%	3.23%	0.00%
Latin America	3.06%	3.06%	0.00%	3.06%	3.06%	0.00%
CARICOM	3.43%	3.43%	0.00%	3.43%	3.43%	0.00%
European Union	3.08%	3.08%	0.00%	3.08%	3.07%	-0.01%
CIS countries	3.06%	3.06%	0.00%	3.06%	3.06%	0.00%
MENA	2.91%	2.91%	0.00%	2.91%	2.91%	0.00%
ECOWAS	1.99%	1.99%	0.00%	1.90%	1.90%	0.00%
Rest of Africa	2.08%	2.08%	0.00%	2.08%	2.08%	0.00%
Mozambique	1.09%	1.09%	0.00%	1.09%	1.09%	0.00%
Botswana	1.75%	1.75%	0.00%	1.76%	1.75%	-0.01%
South Africa	3.16%	3.16%	0.00%	3.16%	3.10%	-0.06%
Namibia	1.38%	1.38%	0.00%	1.48%	1.38%	-0.10%
Rest of SACU	2.67%	2.67%	0.00%	2.68%	2.67%	-0.01%

(Source: authors' calculation)

The reform also changes access to foreign markets for the countries studied in this research. This is illustrated by Table 2.

Access to foreign markets is slightly improved for the EU: from 3.08% to 3.07% in 2035. It is not changed for Mozambique and Botswana, but it is slightly improved for South Africa (by only 6 bp from 3.16% to 3.1%), Namibia (by 10 bp from 1.48% to 1.38%), and the Rest of SACU region (by 1 bp from 2.68% to 2.67%).

Table 2: Protection faced by all exports– 2012/2035 – Baseline -Scenario

	2012			2035		
	Ref	**Sim**	**Variation**	**Ref**	**Sim**	**Variation**
Rest of the World	2.68%	2.68%	0.00%	2.68%	2.68%	0.00%
Asia	4.04%	4.04%	0.00%	4.04%	4.04%	0.00%
North America Free Trade Area	3.23%	3.23%	0.00%	3.23%	3.23%	0.00%
Latin America	3.06%	3.06%	0.00%	3.06%	3.06%	0.00%
CARICOM	3.43%	3.43%	0.00%	3.43%	3.43%	0.00%
European Union	3.08%	3.08%	0.00%	3.08%	3.07%	-0.01%
CIS countries	3.06%	3.06%	0.00%	3.06%	3.06%	0.00%
MENA	2.91%	2.91%	0.00%	2.91%	2.91%	0.00%
ECOWAS	1.99%	1.99%	0.00%	1.90%	1.90%	0.00%
Rest of Africa	2.08%	2.08%	0.00%	2.08%	2.08%	0.00%
Mozambique	1.09%	1.09%	0.00%	1.09%	1.09%	0.00%
Botswana	1.75%	1.75%	0.00%	1.76%	1.75%	-0.01%
South Africa	3.16%	3.16%	0.00%	3.16%	3.10%	-0.06%
Namibia	1.38%	1.38%	0.00%	1.48%	1.38%	-0.10%
Rest of SACU	2.67%	2.67%	0.00%	2.68%	2.67%	-0.01%

(Source: authors' calculation)

Consequently, this trade agreements entails only a small, if not residual, opening of trade borders.

Table 3 indicates the protection applied on goods by a country in column on products originated in the country in row. This is average protection in 2035 in the baseline and in the scenario. For example in 2035 the average protection on goods that Mozambique imposes in the baseline on EU products is 7.48%, while it is 6.33% in the scenario.

EPA is essentially a free trade area. In a classical and influential paper, Viner (1950) pointed out two effects from a free trade area: trade creation and trade diversion. The first effect is beneficial and comes from new trade arising from the elimination of barriers to trade between members of the free trade area. The second one is negative and consists in the replacement of a trade flow between a member of the area and a country not belonging to the area by a trade flow between two members of the area. It implies that the importing country does not import from the cheapest source such that this trade diversion effect is equivalent to a deterioration in a country's terms of trade.

From an *ex ante* analysis of this trade reform, it can be stated that trade creation may not be significant since tariff barriers on the EU side are low and since SADC tariffs on products coming from other SADC countries are already low. The only significant trade creation may happen on goods exported by the EU to Mozambique and South Africa. For these flows, the average protection decreases respectively from 7.48% to 6.33% and from 5.68% to 5.17%. At the same time, on these bilateral flows, trade diversion may happen

since protection imposed by Mozambique and South Africa remains constant on goods coming from countries other than the EU and SADC countries.

Table 3: Protection on goods imposed by country in column on imports coming from country in row–2035 – Baseline -Scenario – Weight=world imports

	EU		**Mozambique**		**Botswana**		**South Africa**		**Namibia**		**Rest of SACU**	
	Baseline	**Scenario**	**Baseline**	**Scenario**	**Baseline**	**Scenario**	**Baseline**	**Scenario**	**Baseline**	**Scenario**	**Baseline**	**Scenario**
EU			7.48%	6.33%	5.37%	5.30%	5.68%	5.17%	2.72%	2.42%	8.76%	8.76%
Mozambique	0.00%	0.00%			0.04%	0.04%	0.01%	0.01%	0.03%	0.03%	7.51%	7.51%
Botswana	0.03%	0.00%	7.18%	7.18%			0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
South Africa	0.19%	0.01%	8.64%	8.64%	0.00%	0.00%			0.00%	0.00%	0.00%	0.00%
Namibia	0.31%	0.01%	5.33%	5.33%	0.00%	0.00%	0.00%	0.00%			0.00%	0.00%
Rest of SACU	0.05%	0.00%	7.18%	7.18%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		

(Source: authors' calculation)

Let us now consider the variation of protection implied by the agreement by sector. Since protection varies only on goods exported by the EU to SADC countries and by non-LDCs SADC countries (Botswana, South Africa, Namibia, Rest of SACU) to the EU, we focus on the variation of protection by sector on these flows.

Table 4: Variation in Protection by sector – (Scenario – Baseline) –2035 – Exporter = EU

	Mozambique	**Botswana**	**South Africa**	**Namibia**	**Rest of SACU**
Vegetables and Fruits	-1.4%	0.0%	0.0%	0.0%	0.0%
Oilseeds	0.0%	0.0%	0.0%	0.0%	0.0%
Other Crops	-1.1%	0.0%	0.0%	0.0%	0.0%
Vegetable Oil	0.0%	0.0%	0.0%	0.0%	0.0%
Other Food	-2.1%	0.0%	-0.1%	-0.1%	0.0%
Textile	-2.5%	0.0%	-2.6%	-2.5%	0.0%
Wearing Apparel	-0.6%	-2.3%	-18.6%	-15.0%	-0.1%
Leather Product	-3.0%	0.0%	0.0%	0.0%	0.0%
Chemicals	-1.7%	0.0%	0.0%	0.0%	0.0%
Motor Vehicles	-0.8%	0.0%	-0.6%	-0.4%	0.0%
Electronics	-3.0%	0.0%	0.0%	0.0%	0.0%
Other Industries	-0.1%	0.0%	-0.7%	0.0%	0.0%
Cereals	0.0%	0.0%	0.0%	0.0%	0.0%
Sugar	-4.3%	0.0%	0.0%	0.0%	0.0%
Cattle	0.0%	0.0%	0.0%	0.0%	0.0%
Other Animal	0.0%	0.0%	0.0%	0.0%	0.0%
Other Natural Resources	-2.4%	0.0%	0.0%	0.0%	0.0%
Fisheries	0.0%	0.0%	-5.9%	-0.2%	0.0%
Fossil Fuel	-0.1%	0.0%	-0.2%	-0.1%	0.0%
Red Meat	-0.4%	0.0%	0.0%	-0.1%	0.0%
White Meat	-6.4%	0.0%	-0.6%	-0.8%	0.0%
Dairy products	-0.5%	0.0%	-0.6%	-0.2%	0.0%
Beverage and Tobacco	-2.1%	0.0%	0.0%	0.0%	0.0%
Wood Products	-0.5%	0.0%	0.0%	0.0%	0.0%
Paper Products	-3.0%	0.0%	0.0%	0.0%	0.0%
Other Mineral	-0.9%	0.0%	0.0%	0.0%	0.0%
Metals	-0.2%	0.0%	0.0%	0.0%	0.0%
Capital Goods	-1.2%	0.0%	0.0%	0.0%	0.0%
Utilities		0.0%			

(Source: authors' calculation)

Table 4 indicates the variation of protection implied by the EPA in 2035 on the EU's exports to SADC countries. The sectors in which Europe benefits from the best improvement in terms of access to SADC countries are Wearing Apparel in South Africa and Namibia and White Meat in Mozambique.

Concerning the protection applied by Europe on products from SADC countries by sector (see Table 5), the sectors where SADC countries benefit from the best improvement in terms of access to European

markets are Sugar for Rest of SACU, Beverages and Tobacco for South Africa, Cattle for Namibia, and Red Meat for Botswana and Namibia.

Table 5: Variation in Protection by sector – (Scenario – Baseline) –2035 – Importer = EU

	Mozambique	**Botswana**	**South Africa**	**Namibia**	**Rest of SACU**
Vegetables and Fruits	0.00%	0.00%	-1.12%	-2.13%	-0.01%
Other Crops	0.00%	0.00%	-0.16%	-0.10%	0.00%
Vegetable Oil	0.00%	0.00%	0.00%	-2.47%	0.00%
Other Food	0.00%	0.00%	-0.93%	-1.17%	-0.05%
Textile	-0.02%	0.00%	-0.07%	-0.24%	0.00%
Wearing Apparel	0.00%	0.00%	-0.19%	-0.85%	0.00%
Leather Product	0.00%	0.00%	0.00%	-0.23%	0.00%
Chemicals	0.00%	0.00%	0.00%	-0.11%	0.00%
Motor Vehicles	0.00%	0.00%	0.00%	-0.03%	0.00%
Electonics	0.00%	0.00%	0.00%	-0.57%	0.00%
Other Industries	0.00%	0.00%	0.00%	0.00%	0.00%
Cereals	0.00%	0.00%	0.00%	0.00%	0.00%
Sugar	0.00%	0.00%	0.00%	-0.02%	-28.11%
Cattle	0.00%	-0.70%	-0.12%	-8.05%	-0.14%
Other Animal	0.00%	0.00%	0.00%	0.00%	0.00%
Other Natural Resources	0.00%	0.00%	0.00%	0.00%	0.00%
Fisheries	0.00%	0.00%	-2.48%	-2.86%	0.00%
Fossil Fuel	0.00%	0.00%	0.00%	0.00%	0.00%
Red Meat	0.00%	-7.89%	0.00%	-7.48%	-0.64%
White Meat	0.00%	0.00%	-0.46%	-1.30%	0.00%
Dairy products	0.00%	0.00%	-1.67%	-0.01%	0.00%
Beverage and Tobacco	-0.03%	0.00%	-11.06%	-1.13%	-0.06%
Wood Products	0.00%	0.00%	0.00%	-0.07%	0.00%
Paper Products	0.00%	0.00%	0.00%	0.00%	0.00%
Other Mineral	0.00%	0.00%	-0.02%	-0.19%	0.00%
Metals	0.00%	0.00%	-0.01%	-0.11%	0.00%
Capital Goods	0.00%	0.00%	0.00%	-0.37%	0.00%

(Source: authors' calculation)

3.2 Impact of the reform on tariff revenues and trade

The direct effect of a cut in import tariffs is on trade and tariff revenues. This is why we firstly look at the impact of the reform on both variables. Table 6 indicates the impact of the reform on export and imports by country (or region) in 2035 and in volume. At the global level, the impact of the reform on trade is modest. World trade of all goods and services increases by only 0.002% in 2035. Some countries obtain a more significant variation in exports and imports (see Table 8), but almost all augmentations are less than 1%. The largest variations are recorded by the Rest of SACU; this is related to the small size of this region but also to a significant increase of sugar exports to the EU (see below). If

Mozambique's and Botswana's trade do not change significantly, this is because barriers on their exports and imports are not significantly affected by the reform (see above).

Table 6: Impact of the reform on total trade by country – % - 2035 – all sectors – Constant US$

	Exports	**Imports**
Rest of the World	0	0
Asia	0	0
North America Free Trade Area	0	0
Latin America	0	0
CARICOM	0	0
European Union	0.01	0.01
CIS countries	0	0
MENA	0	0
ECOWAS	0	0
Rest of Africa	0	0
Mozambique	0.14	0.1
Botswana	0.01	0.05
South Africa	0.11	0.12
Namibia	0.24	0.52
Rest of SACU	0.68	1.73

(Source: authors' calculation)

Table 7 indicates the rate of variation in bilateral trade (in value, in 2035) from row countries toward column countries. The EPA between the EU and the SADC countries leads to trade creation, in particular from the EU to SADC countries (European exports to Mozambique are augmented by almost 4%) and from SADC countries to the EU (Rest of SACU's exports to the EU are augmented by almost 9%). Trade creation does not occur systematically as far as inter-SADC country trade is concerned; as already shown by Table 5, either imports duties are already 0 in the baseline on trade between SADC countries (this is the case, for example, of SADC exports to Botswana, South Africa, and Namibia) or import duties are positive but unaffected by the reform (this is the case of SADC exports to Mozambique).

There are also small diversion effects. While European exports to Mozambique are increased by almost 4%, exports from Asia, NAFTA, and Latin America to this country are decreased by 0.4%. This trade diversion effects are small and not systematic.

International trade may also be affected by macroeconomic adjustment. For example, Table 3 and Table 4 indicate that while Mozambique decreases its protection on imports (see Table 3), the EPA does not decrease protection faced by its worldwide exports (see Table 4). Therefore, the first effect of the reform is an augmentation of imports. Since the current account balance has to remain constant in proportion of GDP, Mozambique's real exchange rate depreciates such that exports increase; indeed, Mozambique's exports to all regions outside SADC countries and the EU are augmented. The opposite effect occurs in South Africa.

Table 7: Impact of the reform on bilateral trade in value – FOB price – % - 2035 – all sectors – Exporter in row, importer in column

	Rest of the World	**Asia**	**North America Free Trade Area**	**Latin America**	**CARICOM**	**European Union**	**CIS countries**	**MENA**	**ECOWAS**	**Rest of Africa**	**Mozambique**	**Botswana**	**South Africa**	**Namibia**	**Rest of SACU**
Rest of the World	0	0	0	0	0	0	0	0	0	0	-0.29	0.05	0.01	0.49	1.71
Asia	0	0	0	0	0	0	0	0	0	0.01	-0.36	0.06	-0.07	0.62	1.67
NAFTA	0	0	0	0	0	0	0	0	0	0	-0.37	0.05	-0.01	0.59	1.91
Latin America	0	0	0	0	0	-0.02	0	0	0	0.01	-0.3	0.04	-0.04	0.16	1.71
CARICOM	0	0	0	0	0	-0.01	0	0	0	0.01	-0.14	0.04	0	0.19	0.99
European Union	0	0	0	0	0	0	0	0	0	0.01	3.81	0.07	0.59	0.79	1.51
CIS countries	0	0	0	0	0	0	0	0	0	0	-0.19	0.04	0.02	0.38	1.54
MENA	0	0	0	0	0	0	0	0	0	0.01	-0.32	0.05	-0.01	0.48	1.53
ECOWAS	0	0	0	0	0	0	0	0	0	0	-1.44	0.07	-0.02	0.55	2.15
Rest of Africa	0	0	0	0	0	-0.02	0	0	0	0.01	-0.39	0.09	-0.03	0.47	5.04
Mozambique	0.19	0.08	0.11	0.12	0.1	0.15	0.09	0.1	0.13	0.1		0.08	0.07	0.73	2.56
Botswana	-0.2	-0.08	-0.07	-0.07	-0.07	0.11	-0.05	-0.06	-0.08	-0.12	-0.72		-0.22	0.41	1.86
South Africa	-0.06	-0.04	-0.04	-0.04	-0.03	0.88	-0.04	-0.04	-0.04	-0.03	-0.5	0.04		0.52	1.97
Namibia	-0.92	-0.48	-0.53	-0.46	-0.48	1.9	-0.59	-0.45	-0.34	-0.65	-0.68	-0.39	-0.78		1.41
Rest of SACU	-0.93	-0.58	-1.65	-1.13	-0.83	8.8	-0.17	-1.04	-1.48	-2.25	-2.27	-0.4	-0.12	-1.26	0.27

(Source: authors' calculation)

At the level of big sectors (Agro-food; Industry; Services), Table 8 shows how trade is impacted for the main countries/regions of concern in this study.

The largest increase is in exports of agro-food products from the Rest of SACU region; these are augmented by almost one-third in value. This is related to the liberalization of the sugar sector in Europe to the benefit of Swaziland.

The other sectors benefiting from this agreement are the agro-food sectors in Botswana, South Africa, and Namibia. This is related to the results obtained in Table 5; with this agreement, Botswana obtains a substantial gain in market access in the red meat sector while for Namibia, new market access is obtained in the cattle and red meat sectors; for South Africa, this is in the Beverage & Tobacco sector.

Table 8: Impact of the reform on exports and imports in value by country and Big Sectors - % - Scenario/Baseline - 2035

	Exports			**Imports**		
	Agro-food	**Industry**	**Services**	**Agro-food**	**Industry**	**Services**
Rest of the World	-0.01	0.00	0.00	0.00	0.00	0.00
Asia	0.00	0.00	0.00	0.00	0.00	0.00
North America Free Trade Area	0.00	0.00	0.00	0.00	0.00	0.00
Latin America	-0.01	0.00	0.00	0.00	0.00	0.00
CARICOM	-0.01	0.00	0.00	0.00	0.00	0.00
European Union	-0.02	0.01	0.00	0.06	0.00	0.00
CIS countries	-0.01	0.00	0.00	0.00	0.00	0.00
MENA	-0.02	0.00	0.00	0.00	0.00	0.00
ECOWAS	-0.01	0.00	0.00	0.00	0.00	0.00
Rest of Africa	-0.02	0.00	0.00	-0.01	0.00	0.00
Mozambique	-0.01	0.14	0.08	0.05	0.15	-0.10
Botswana	4.00	-0.05	-0.05	0.06	0.04	0.07
South Africa	2.21	-0.04	-0.02	0.19	0.12	0.04
Namibia	3.58	-0.34	-0.36	0.71	0.50	0.51
Rest of SACU	33.89	-1.23	-0.42	3.85	1.63	1.46

(Source: authors' calculation)

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Table 9 provides how exports by sectors in the main countries in this study vary, first by a rate of variation (in value, in % and in 2035) and second in variation in US$ Mios.

Concerning the EU, only two sectors augment exports in 2035 by more than US$ 100 Mios: motor vehicles (US$ 269.87 Mios), wearing apparel (US$ 122.09 Mios).[5] Most of the augmentation of EU exports of motor vehicles is toward South Africa (US$ 222.6 Mios; this represents a modest augmentation by 1.68%). European exports of wearing apparel goods are raised by US$ 112.7 Mios toward South Africa; this represents a very significant increase by 70% (in value) which must be related

[5] For comparison, in a previous study on the EPA between EU and West Africa, we concluded that four sectors will see their exports augmented by more than US$ 1 bln in 2035, thanks to the reform: fossil fuel (US$ 5.3 bln), capital goods (US$ 3.2 bln), other crops (US$ 1.6 bln), metals (US$ 1.3 bln).

to the observed liberalization (in Table 6) of these products exported by the EU toward South Africa. However, European exports of Beverage and Tobacco are reduced by US$ 102.3 Mios, still in 2035.

On the African side, significant augmentations of exports in value are observed at the benefits of South Africa in the Beverage and Tobacco sector (US$ 411.6 Mios) and the Vegetable and Fruit sector (US$ 118.6 Mios), but also to the benefit of the Rest of SACU in the sugar sector (US$ 148 Mios).

Table 9: Impact of the reform on exports in value by country and by sectors - 2035

	Rate of variation; Scenario/Baseline (%)						Variation: Scenario - baseline (US$ Mios)					
	EU	**Moz.**	**Bots.**	**Sth Afr**	**Nam.**	**RSACU**	**EU**	**Moz.**	**Bots.**	**Sth Afr**	**Nam.**	**RSACU**
Vegetables and Fruits	-0.07	0.08	-0.12	1.60	4.26	-1.02	-41.35	0.32	0.00	118.65	4.23	-0.52
Oilseeds	0.01	0.08	-0.17	-0.06	-0.58	-1.38	0.52	0.09	0.00	-0.10	0.00	-0.04
Other Crops	0.01	0.10	-0.14	0.11	-0.48	-5.01	2.95	0.44	0.00	1.12	-0.08	-1.23
Vegetable Oil	0.00	0.17	-0.22	0.05	2.85	-2.38	1.02	0.04	0.00	0.46	0.21	-0.01
Other Food	0.00	0.09	0.03	0.63	1.83	-0.95	-0.51	0.25	0.01	30.90	26.19	-1.54
Textile	0.06	0.20	-0.13	0.16	-0.19	-0.68	68.27	0.03	-0.07	1.66	-0.22	-1.16
Wearing Apparel	0.13	-0.04	-0.10	0.21	0.77	-2.31	122.09	0.00	-0.05	1.57	0.27	-31.20
Leather Product	0.01	0.19	0.32	0.00	-0.12	-2.39	7.16	0.00	0.01	0.03	-0.08	-0.04
Chemicals	0.00	0.19	-0.08	-0.07	-0.54	-1.85	49.11	0.07	-0.07	-13.86	-10.99	-12.45
Motor Vehicles	0.02	0.25	-0.05	0.07	-0.56	-1.26	269.87	0.04	-0.11	14.93	-2.35	-0.14
Electonics	0.01	0.25	0.06	-0.33	-0.56	-1.91	26.45	0.09	0.01	-6.78	-0.66	-1.38
Other Industries	0.01	0.16	-0.17	-0.06	-0.74	-2.22	10.55	0.07	-2.38	-3.26	-3.55	-2.58
Construction	0.00	0.13	-0.07	-0.03	-0.27	-0.91	0.12	0.08	-0.03	-0.08	-0.36	-0.13
Cereals	0.01	0.06	-0.16	-0.06	-0.79	-1.22	2.70	0.02	-0.01	-2.17	-0.03	-0.02
Sugar	-0.40	-0.45	-0.12	-0.06	-0.63	163.17	-32.45	-1.25	0.00	-0.51	-0.02	148.21
Cattle	0.00	0.08	-0.40	0.05	-0.78	-1.05	-0.08	0.00	-0.14	0.04	-2.55	0.00
Other Animal	0.01	0.08	-0.10	-0.03	-0.42	-0.92	1.89	0.00	0.00	-0.48	-0.16	-0.08
Other Natural Resources	0.00	0.02	-0.01	-0.01	-0.11	-0.21	2.07	0.24	-0.84	-3.78	-2.53	-1.28
Fisheries	0.00	-0.21	0.38	1.51	5.87	-0.90	0.55	-0.01	0.00	5.37	2.66	0.00
Fossil Fuel	0.01	0.03	-0.08	-0.01	-0.52	0.17	39.38	0.68	0.00	-1.76	0.00	2.03
Red Meat	-0.08	0.12	21.66	0.02	29.60	-1.81	-19.09	0.00	11.20	0.04	56.67	-0.26
White Meat	0.02	0.21	-0.48	0.69	-0.96	-3.26	14.65	0.01	-0.25	3.82	-0.32	-0.03
Dairy products	0.01	0.13	-0.22	0.69	-1.27	-2.04	6.58	0.00	-0.03	2.66	-0.32	-0.07
Beverage and Tobacco	-0.07	0.03	-0.04	10.61	0.01	-0.52	-102.35	0.00	-0.02	411.63	0.01	-0.34
Wood Products	0.00	0.18	-0.05	-0.06	-0.72	-1.22	1.81	0.14	-0.02	-1.11	-0.98	-0.06
Paper Products	0.00	0.35	0.11	-0.12	-0.83	-1.72	11.13	0.01	0.01	-5.78	-0.19	-0.78

Other Mineral	0.00	0.18	0.04	0.01	-0.34	-0.87	2.64	0.03	0.00	0.13	-0.14	-0.04
Metals	0.00	0.17	-0.22	-0.06	-0.16	-0.79	18.43	21.46	-1.48	-76.97	-4.74	-0.84
Capital Goods	0.00	0.22	-0.11	-0.11	-0.87	-2.27	80.86	0.45	-0.26	-26.76	-4.84	-7.83
Utilities	0.00	0.08	-0.10	0.02	-0.49	-0.21	-0.01	3.68	-0.02	0.22	-0.14	-0.25
Trade	0.00	0.08	-0.06	-0.04	-0.40	-1.15	9.96	0.04	-0.13	-1.73	-0.19	-0.24
Transportation	0.00	0.09	-0.03	-0.01	-0.32	-0.48	4.80	0.42	-0.20	-1.41	-1.32	-0.39
Business Services	0.00	0.08	-0.06	-0.03	-0.26	-0.22	5.65	0.19	-0.57	-3.31	-0.56	-2.24
Other services	0.00	0.05	-0.05	-0.02	-0.29	-0.13	0.44	0.03	-0.11	-0.97	-1.02	-0.03
Public Services	0.00	0.15	-0.07	-0.02	-0.78	-1.72	0.23	0.12	-0.28	-0.64	-1.29	-2.80

(Source: authors' calculation)

Table 10 provides how imports by sectors in the main countries are affected, again first by a rate of variation (in value, in % and in 2035) and second in variation in US$ Mios.

On the European side, as expected, the largest augmentations of imports in value take place in the beverage and tobacco (US$ 278.9 Mios) and sugar (US$ 78.9 Mios) sectors. On the African side, it takes place in the motor vehicle sector in South Africa (US$ 146.5 Mios).

It has often been underlined that custom duties are an essential element of public revenues in Africa while the collection of domestic indirect or direct taxes is not efficient. One worrying element for African countries concerning the EPA is the loss of custom duties. Bouët, Laborde, and Traoré (2014) show that the EPA between the EU and West Africa leads to a significant loss of custom duties for West African countries.

Table 10: Impact of the reform on imports in value by country and by sectors - 2035

	Rate of variation; Scenario/Baseline (%)						Variation: Scenario - baseline (US$ Mios)					
	EU	**Moz.**	**Bots.**	**Sth Afr.**	**Nam.**	**RSACU**	**EU**	**Moz.**	**Bots.**	**Sth Afr.**	**Nam.**	**RSACU**
Vegetables and Fruits	0.05	-0.11	0.01	0.27	0.70	1.68	38.42	-0.20	0.00	1.05	0.09	0.16
Oilseeds	-0.01	-0.10	0.11	0.08	0.95	1.62	-1.59	-0.04	0.00	0.05	0.01	0.06
Other Crops	-0.02	-0.06	0.08	0.44	0.01	18.06	-13.07	-0.08	0.01	5.86	0.00	7.21
Vegetable Oil	-0.01	-0.07	-0.03	0.05	0.41	1.62	-4.10	-0.57	0.00	1.34	0.04	0.90
Other Food	0.01	0.04	0.06	0.09	0.96	1.99	20.76	0.68	0.03	5.48	1.56	0.66
Textile	0.01	0.00	-0.03	0.42	0.80	0.80	27.41	-0.02	-0.05	33.10	1.44	3.84
Wearing Apparel	0.00	-0.02	0.09	1.39	4.74	2.66	6.73	-0.03	0.14	84.93	2.90	1.05
Leather Product	0.00	0.19	0.03	0.04	0.54	1.85	0.59	0.40	0.01	1.64	0.36	0.49
Chemicals	0.00	0.20	0.08	0.03	0.40	2.18	11.93	7.32	0.18	12.28	3.14	4.47
Motor Vehicles	0.01	0.08	0.05	0.40	0.89	2.25	44.79	1.17	0.13	146.55	3.29	5.39
Electonics	0.00	1.12	0.05	0.03	0.82	2.44	5.32	7.40	0.13	6.20	2.39	1.99
Other Industries	0.00	0.01	0.12	0.22	0.68	2.53	-0.04	0.05	0.12	8.18	0.62	1.56
Construction	0.00	-0.10	0.11	0.04	0.75	4.31	-0.86	-0.24	0.03	0.08	0.21	1.72
Cereals	-0.01	-0.12	0.10	0.16	1.05	2.47	-4.48	-0.92	0.04	3.01	0.64	0.19
Sugar	0.68	-0.07	0.09	0.26	0.61	76.86	78.92	-0.12	0.00	0.80	0.06	0.28
Cattle	-0.01	-0.13	1.55	-0.71	7.16	1.78	-0.82	0.00	0.02	-2.54	0.06	0.01
Other Animal	0.00	-0.12	0.34	0.05	0.20	3.72	-0.86	-0.04	0.04	0.09	0.01	0.05
Other Natural Resources	0.00	0.21	0.04	-0.01	-0.02	1.01	-1.65	0.23	0.11	-0.88	-0.22	0.14
Fisheries	0.02	-0.09	0.00	3.36	1.11	1.80	3.58	0.00	0.00	2.75	0.04	0.02
Fossil Fuel	0.00	-0.02	0.02	0.02	0.35	0.77	21.40	-0.55	0.31	14.70	6.85	3.73
Red Meat	0.14	-0.21	0.60	0.11	1.72	2.41	38.26	-0.10	0.01	0.22	0.22	0.56
White Meat	0.00	1.41	0.05	0.69	0.58	1.86	-0.10	1.45	0.01	7.17	1.12	0.92
Dairy products	0.00	-0.03	0.06	1.05	1.54	2.54	-0.20	-0.04	0.03	3.49	0.31	0.17
Beverage and Tobacco	0.34	0.83	0.02	0.11	0.51	1.60	278.92	2.25	0.03	1.91	1.46	1.59
Wood Products	0.00	0.00	0.10	0.03	0.87	2.65	-0.18	0.01	0.07	1.28	0.87	0.17
Paper Products	0.00	0.67	0.06	0.09	0.91	1.39	-1.82	2.93	0.02	4.19	0.86	0.70

Other Mineral	0.00	0.12	0.09	0.04	0.72	2.84	-0.81	0.79	0.10	2.18	0.78	0.80
Metals	0.00	0.00	0.07	0.02	0.62	2.43	27.96	0.09	0.56	3.35	4.41	2.11
Capital Goods	0.00	0.19	0.05	0.05	0.75	2.94	9.00	8.48	0.70	28.71	8.35	6.73
Utilities	0.00	0.03	0.08	0.06	0.45	0.97	-0.18	0.13	0.14	2.90	1.57	0.14
Trade	0.00	-0.18	0.07	0.06	0.38	1.84	-3.40	-0.64	0.07	6.58	0.24	3.14
Transportation	0.00	-0.08	0.06	0.03	0.55	1.26	0.59	-0.45	0.15	3.42	0.80	4.26
Business Services	0.00	-0.06	0.07	0.04	0.46	1.24	-4.88	-0.92	0.54	2.48	1.61	12.05
Other services	0.00	-0.09	0.07	0.04	0.60	1.60	0.67	-0.12	0.07	1.12	0.43	3.00
Public Services	0.00	-0.26	0.08	0.01	0.89	2.45	-5.00	-1.35	0.09	0.36	0.70	2.35

(Source: authors' calculation)

In the case of the EPA between the EU and SADC, this conclusion does not apply. Of course, the implementation of the EPA implies a loss of custom duties for Mozambique, South Africa, and Namibia but this loss is small in magnitude (see Table 11). This is explained by the fact the EPA does not entail a substantial reduction in custom duties for these countries and Botswana and the Rest of SACU even gain custom revenues. For these two countries/regions this is due to a slightly decrease of their average protection, from 1.76% to 1.75% for Botswana and from 2.68% to 2.67% for the Rest of SACU, coupled with a significant increase in the volume of imports (+0.06% for Botswana and +1.99% for the Rest of SACU.

Table 11: Impact of the reform on the collection of import duties– Scenario/Baseline – US$ Mios - 2035

	Percentage
European Union	-0.34
Mozambique	-1.43
Botswana	0.03
South Africa	-0.58
Namibia	-0.15
Rest of SACU	1.60

(Source: authors' calculation)

3.3 Impact of the reform on production

We evaluate now what is the impact of the trade reform on production by sector. The first-order effect of a trade agreement on production is through its impact on national exports (when they augment, the direct effect is to augment production, other things being equal) and national imports (when they augment, the direct effect is to decrease production, other things being equal).

But there are second-order effect: by changing the price of intermediate goods, by affecting the equilibrium on productive factors markets, a trade reform also affects the cost of inputs and consequently the level of production. Another effect consists in changing households' income and public revenues and consequently their level of demand of each good.

Table 12 indicates the impact of the trade reform on production in volume by sector in 2035, with the rate of variation on the left and the distribution of production in 2035 in the reference scenario on the right. On the European side, the impact on sectoral production is close to zero with only a significant effect on production in the sugar sector where production decreases by 0.27%; this is related to the expansion of sugar imports from Eswatini. The largest augmentation in European production is obtained in the wearing apparel and the textile sectors, where production is increased by 0.03%.

On the African side, the largest augmentation in relative terms is obtained in the sugar sector in the Rest of SACU, where production is increased by 80.85%; however, this sector represents only 0.6% of this region's total production. Other significant increases of production are obtained in the red meat sector

in Namibia (+14.02%), in the other crops sector in the Rest of SACU (+10.15%), and in the cattle sector in Namibia (+3.37%).

While augmentation of production in the sugar sector in Rest of SACU and in the red meat and the cattle sectors in Namibia is directly explained by the opening of European borders to these commodities and related augmentation of SADC countries' exports, the augmentation of production of the other crops in the Rest of SACU is explained by the augmentation of local production of sugar; the other crops provide around 30% of the value of intermediate consumption of the sugar sector.

Table 12: Impact of the reform on production by country and sector - % - 2035 — Constant US$

	Rate of Variation - Scenario/Baseline (%)						Share in total production - Baseline					
	EU	**Mozambique**	**Botswana**	**South Africa**	**Namibia**	**Rest of SACU**	**EU**	**Mozambique**	**Botswana**	**South Africa**	**Namibia**	**Rest of SACU**
Agro-food	-0.02	-0.02	0.31	0.33	1.31	3.85	5.9%	15.5%	11.0%	7.1%	17.3%	17.3%
Industry	0.01	0.07	-0.06	-0.05	-0.25	-0.52	28.2%	28.3%	26.8%	35.8%	27.7%	28.3%
Services	0.00	0.01	0.01	0.00	0.13	0.78	65.9%	56.2%	62.1%	57.1%	56.5%	54.4%
Vegetables and Fruits	-0.06	0	-0.05	0.79	0.68	0.46	0.2%	3.7%	0.4%	0.5%	0.8%	3.3%
Oilseeds	0.01	0.03	-0.05	0.01	0.21	0.15	0.1%	0.4%	0.0%	0.0%	0.0%	0.2%
Other Crops	0	0.08	-0.06	0.2	-0.63	10.15	0.2%	0.8%	0.1%	0.1%	0.0%	0.5%
Vegetable Oil	0	0.09	-0.25	0.01	1.38	-0.5	0.1%	0.3%	0.0%	0.2%	0.0%	0.5%
Other Food	0	-0.02	0	0.07	1.06	0.47	1.8%	2.4%	1.3%	2.1%	4.1%	3.1%
Textile	0.03	0	-0.14	-0.19	0.07	-0.24	0.6%	0.2%	0.1%	0.7%	1.2%	1.4%
Wearing Apparel	0.03	0	-0.11	-0.19	-0.79	-2.17	0.5%	0.3%	0.2%	1.1%	0.3%	5.5%
Leather Product	0.01	-0.2	-0.09	-0.02	-0.23	-0.29	0.3%	0.1%	0.1%	0.4%	0.2%	0.1%
Chemicals	0	-0.18	-0.04	-0.02	-0.44	-1.11	4.6%	1.0%	0.8%	5.7%	5.1%	4.0%
Motor Vehicles	0.01	-0.09	-0.07	-0.1	-0.31	0.88	3.5%	0.4%	0.4%	4.2%	1.4%	0.6%
Electonics	0.01	-1.44	-0.02	-0.07	-0.12	-0.49	1.0%	0.3%	0.0%	0.6%	0.9%	0.6%
Other Industries	0	0.12	-0.12	-0.02	-0.61	-0.85	0.8%	0.2%	4.6%	1.9%	1.0%	1.0%
Construction	0	0.03	0.04	0.01	0.43	3.21	7.6%	6.6%	16.6%	4.7%	6.8%	2.6%
Cereals	0	0.01	-0.02	0.05	0.53	0.52	0.2%	3.4%	0.7%	0.3%	0.4%	0.7%
Sugar	-0.27	-0.21	-0.06	0.17	-0.64	80.85	0.1%	0.8%	0.0%	0.2%	0.0%	0.6%
Cattle	-0.01	-0.03	1.15	0.03	3.37	0.62	0.3%	0.2%	1.4%	0.4%	1.4%	0.8%
Other Animal	0.01	-0.05	0.23	-0.02	-0.25	0.45	0.3%	0.5%	0.4%	0.5%	0.3%	0.6%
Other Natural Resources	0	0.04	-0.02	-0.02	-0.19	0.12	0.5%	3.8%	15.2%	1.9%	6.9%	4.1%
Fisheries	-0.01	0	0	0.22	0.51	0.59	0.1%	0.8%	0.0%	0.0%	3.0%	1.8%

Fossil Fuel	0	0.04	-0.05	-0.01	-0.21	0.21	2.6%	2.6%	0.2%	3.6%	0.0%	4.7%
Red Meat	-0.05	0.02	2.77	0	14.02	0.43	0.2%	0.2%	0.7%	0.5%	0.6%	1.1%
White Meat	0.01	-0.92	-0.05	-0.02	-0.7	-0.63	0.5%	0.1%	2.0%	0.4%	0.2%	0.1%
Dairy products	0	-0.01	-0.07	0	0.08	0.72	0.9%	0.2%	2.1%	0.4%	1.3%	0.9%
Beverage and Tobacco	-0.06	-0.03	0.01	1.21	0.13	0.73	1.0%	1.6%	1.9%	1.4%	3.5%	3.1%
Wood Products	0	0.03	-0.01	-0.03	-0.22	1.41	0.7%	2.1%	0.6%	0.5%	0.5%	0.8%
Paper Products	0	-1.03	-0.03	0.02	0.02	-0.02	2.1%	0.2%	0.6%	1.9%	0.8%	1.1%
Other Mineral	0	0	0	0	0.19	1.99	1.1%	1.5%	0.5%	0.9%	0.7%	0.4%
Metals	0	0.2	-0.18	-0.07	-0.18	0.82	3.5%	14.3%	2.8%	8.1%	6.1%	1.2%
Capital Goods	0	-0.27	-0.12	-0.05	-0.4	-0.7	6.3%	1.2%	0.6%	4.3%	2.6%	2.7%
Utilities	0	0.12	0	-0.01	-0.03	0.54	2.0%	13.3%	1.2%	1.4%	1.7%	2.0%
Trade	0	-0.09	0	0.02	-0.05	0.59	8.3%	7.8%	9.9%	9.8%	11.7%	14.9%
Transportation	0	0.02	0	0.01	0.14	0.66	5.5%	8.0%	4.0%	4.2%	6.2%	5.1%
Business Services	0	0.03	-0.01	0	0.16	0.67	20.3%	8.6%	11.9%	18.2%	13.7%	15.6%
Other services	0	-0.03	0	0.01	0.23	1.43	6.8%	4.8%	5.1%	5.7%	7.1%	4.5%
Public Services	0	-0.1	0.01	-0.01	0.01	0.39	15.4%	7.2%	13.3%	13.1%	9.5%	9.8%

(Source: authors' calculation)

3.4 Impact of the reform on factor markets

Table 13 points out the impact of the EPA reform on factors' real remuneration. Concerning the European Union, the impact is close to being nil. Concerning Western African countries, it is worth noting that the reform is positive for unskilled labor, skilled labor and land, while being either positive or negative for capital and natural resources. A positive impact on unskilled labor's remuneration in particular is important for the effect on poverty. However, the effects are small.

As noted earlier, this reform is positive for agricultural and agro-food sectors in SADC countries; this is confirmed here since real remuneration of land is positively affected by this reform in these countries.

The last column of Table 13 indicates the change in the consumption price index implied by the reform. The implementation of the EPA leads to a reduction of border protection that reduces consumption prices of imported goods, and indirectly of domestic goods thanks to a competition effect. On the other side, the European Union opens its borders to goods coming from SADC countries. This leads to an expansion of exports and production in these countries, this effect pushing up domestic prices. The first effect is dominating in Mozambique, while the opposite takes place in other countries

Table 13: Rate of Variation in factors' real remuneration and consumption price- 2035 - Scenario / Baseline - %

	Unskilled labor	**Skilled labor**	**Capital**	**Land**	**Natural Resources**	**Consumer Price Index**
European Union	0.00	0.00	0.00	-0.02	0.01	0.00
Mozambique	0.00	0.00	0.04	0.02	0.05	-0.04
Botswana	0.02	0.00	-0.01	0.57	-0.03	0.03
South Africa	0.02	0.00	0.01	0.28	-0.11	0.00
Namibia	0.26	0.24	-0.12	1.76	0.11	0.12
Rest of SACU	1.05	0.95	-0.58	2.73	-0.43	0.25

(Source: authors' calculation)

Table 14 presents the reallocation of unskilled and skilled labor between formal and informal sectors but also between urban and rural sectors. More precisely we show the impact on the share of unskilled labor employed in urban and informal sectors in total unskilled labor in 2035. For example in Mozambique, the EPA augments the share of unskilled labor working in formal sectors by 0.01%.

While in Mozambique, Botswana, and South Africa, the reform does not modify significantly the distribution of production and consequently of productive factors across sectors and/or formal vs. informal categories of sectors and rural vs. urban categories of sectors, the reform entails a significant augmentation of activity in the sectors Sugar and Other Crops in the Rest of SACU and in the sectors Red Meat and Cattle in Namibia. Consequently under these three scenarios, a migration from urban to rural activities and a reallocation from formal to informal activities take place. The most significant reallocation in relative terms occurs in the Rest of SACU where around 0.5% of the total unskilled labor

force migrates from urban to rural activities and around 0.44% of total unskilled labor force is reallocated from formal to informal activities.

Table 14: Variation in the Share of Unskilled Labor Employed in Urban and Informal Sectors in Total Unskilled Labor - %– 2035

	Unskilled labor in formal sectors	**Unskilled labor in urban sectors**
Mozambique	0.01	0.00
Botswana	-0.03	-0.03
South Africa	-0.01	-0.01
Namibia	-0.11	-0.12
Rest of SACU	-0.44	-0.50

(Source: authors' calculation)

3.5 Impact of the reform on macroeconomic variables

Table 15 presents the macroeconomic results, in particular how the Gross Domestic Product (GDP) and the welfare (equivalent variation) are affected by the reform. For all countries outside Western Africa there is almost no impact of the reform on GDP and welfare (real income). For SADC Africa's countries the results are positive but small, except for the Rest of SACU where GDP is increased by 0.89% and real income by 1.15%.

Table 15: Rate of variation of GDP (Constant US$) and real income - 2035- scenario/baseline-%

	GDP	**Real Income**
Rest of the World	0	0
Asia	0	0
North America Free Trade Area	0	0
Latin America	0	0
CARICOM	0	0
European Union	0	0
CIS countries	0	0
MENA	0	0
ECOWAS	0	0
Rest of Africa	0	0
Mozambique	0.01	0
Botswana	0.01	0.01
South Africa	0.01	0.01
Namibia	0.19	0.26
Rest of SACU	0.89	1.15

(Source: authors' calculation)

GDP is substantially increased in the Rest of SACU thanks to an expansion of the sugar sector that benefits from a substantial augmentation of exports toward the EU and also an expansion of other crops that benefits from the expansion of the local sugar sector. Consequently, remunerations of productive

factors are augmented (see Table 13); in particular those of labor and land and agents' real income are raised.

Real income is here defined as an equivalent variation, the monetary amount the representative agent would be indifferent about accepting in place of the implementation of the EPA reform. So the reform increases the representative agent's real income in 2035 in each SADC country.

However, this welfare does not account for the provision of a public good by the public sector. Indeed in case of a loss of public revenues associated with the partial removal of custom duties on products imported from the EU, this loss is not compensated while the model imposes that the public deficit is constant in proportion of Gross Domestic Product. If public revenues do not adjust, public expenses make the adjustment. However, either this loss is small or there is a gain in public revenues as explained earlier (see Table 11).

4. Robustness analysis

In order to verify robustness of our results we check if the implementation of the Dual-Dual modelling has significantly influenced the results.

We conduct a sensitivity analyses by implementing the same scenario without the dual-dual modelling.

We do not show all the results since this would be too long. We only show the results concerning the impact of the reform on trade, then on GDP and welfare, then on the collection of import duties.

Table 16: Impact of reform on trade – Sensitivity Analysis – 2035 - %

	Exports		**Imports**	
	MIRAGRODEP_DD	**MIRAGRODEP**	**MIRAGRODEP_DD**	**MIRAGRODEP**
Rest of the World	0	0	0	0
Asia	0	0	0	0
NAFTA	0	0	0	0
Latin America	0	0	0	0
CARICOM	0	0	0	0
European Union	0.01	0.01	0.01	0.01
CIS countries	0	0	0	0
MENA	0	0	0	0
ECOWAS	0	0	0	0
Rest of Africa	0	0	0	0
Mozambique	0.14	0.13	0.1	0.09
Botswana	0.01	0.02	0.05	0.06
South Africa	0.11	0.11	0.12	0.12
Namibia	0.24	0.24	0.52	0.55
Rest of SACU	0.68	0.85	1.73	1.99

(Source: authors' calculation)

This sensitivity analysis shows that the results of this modelling exercise obtained with the dual-dual modelling are not significantly dependent on this assumption. On Table 16, this sensitivity analysis is illustrated by the impact on trade. For each variable, exports then imports, the first column recalls the results obtained in the previous section (i.e., with dual-dual modelling), then we indicate the results obtained under the traditional MIRAGRODEP framework. Table 16 clearly demonstrates that this assumption does not have a significant impact on how trade is affected by the reform. There is no inversion of sign and results are barely changed.

Table 17: Impact of reform on GDP and welfare – Sensitivity Analysis – 2035 - %

	GDP (Constant US$)		**Welfare**	
	MIRAGRODEP_DD	**MIRAGRODEP**	**MIRAGRODEP_DD**	**MIRAGRODEP**
Rest of the world	0	0	0	0
Asia	0	0	0	0
NAFTA	0	0	0	0
Latin America	0	0	0	0
CARICOM	-0.01	0	-0.02	-0.02
European Union	0.01	0.01	0.02	0.02
CIS	0	0	0	0
MENA	0	0	-0.01	-0.01
Nigeria	0	-0.01	-0.09	-0.1
Senegal	0.35	0.33	-0.15	-0.16
Benin	-0.17	-0.17	-0.35	-0.35
Burkina Faso	0.27	0.27	0.18	0.18
Cote d'Ivoire	0.31	0.33	0.33	0.35
Ghana	0.03	0.03	-0.16	-0.16
Rest of ECOWAS	-0.07	-0.07	-0.28	-0.28
Togo	-0.18	-0.18	-0.5	-0.48
Rest of Africa	0	0	-0.01	-0.01

(Source: authors' calculation)

With Table 17 and Table 18, we verify that neither the impact of EPA on welfare and GDP, nor its impact on the collection of import duties is significantly modified by the introduction of the dual-dual modelling.

Table 18: Impact of reform on collection of import duties - % – Sensitivity Analysis

	MIRAGRODEP_DD	MIRAGRODEP
Rest of the world	0	0
Asia	0	0
NAFTA	0	0
Latin America	0	0
CARICOM	-0.2	-0.1
European Union	-0.3	-0.3
Community of Independant States	0	0
Middle East and North Africa	0	0
Nigeria	-13.1	-13.1
Senegal	-22.3	-22.3
Benin	-7.5	-7.5
Burkina Faso	-25.8	-25.8
Cote d'Ivoire	-17	-16.9
Ghana	-14.2	-14.1
Rest of ECOWAS	-10.4	-10.3
Togo	-10.9	-10.8
Rest of Africa	0	0

(Source: authors' calculation)

5. Concluding remarks

The objective of this Technical Paper was to present a new version of the MIRAGRODEP model. MIRAGRODP-DD is a dynamic multi-country multi sector General Equilibrium model with endogenous rural-urban labor mobility and reallocation of unskilled labor between formal and informal sectors. We illustrate this new model by an evaluation of the economic, trade and poverty impact of the Economic Partnership Agreement between the European Union and the SADC countries.

The agreement have some specificities. First, it is not a full free trade agreement implemented amongst the EU and these six African countries because these six countries were members of two different free trade areas before the implementation of this EPA[6]. In addition, a clause allows a certain number of products to be exempted from liberalization on the African side.

Second many products are already exchanged under free trade. Indeed, amongst the flows from African countries to the EU, almost all the lines are already under free trade without the agreement with a high concentration of exports on a few lines.

As a consequence the agreements yield a small shock in terms of reduction in trade barriers and we conclude that globally, the impact is positive but small (if not tiny) for SADC countries. Also, unlike

[6] The Southern African Development Community (SADC), which is a regional community gathering Angola, Botswana, Congo DR, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe, and the Southern African Custom Union (SACU) which gathers Botswana, Lesotho, Mozambique, Namibia, South Africa, and Swaziland

West Africa, this EPA agreement does not raise a major concern in terms of fiscal adjustment. Custom tariffs are used to represent an important part of public revenues in African countries. However, this study points out that the EPA entails only a small reduction in custom revenues, if not a positive one.

Evaluating trade agreements with this new version of the MIRAGRODEP model which tackles rural-urban migration of labor and reallocation of labor between formal and informal activities is a progress since these are important features of African economies. However, there are still some important avenues of research like implementing both formal and informal subsectors in each sector of activity, improving the main obstacles met by agricultural supply in these countries, and disaggregating households in order to understand the implications of a reform at the household level, We issues will be addressed in future research.

6. References

Agenor, P.R., Chen, D. and Grimm, M., 2004, Linking Representative Household Models with Household Surveys for Poverty Analysis. A Comparison of Alternative Methodologies, World Bank Policy Research Working Paper No. 3343, Washington DC: The World Bank

Benjamin, N., and M. A., Mbaye, 2012, *Les entreprises informelles de l'Afrique de l' Ouest francophone. Taille, productivite et institutions.* Collections L'Afrique en Developpement, The World Bank.

Berisha-Krasniki, V., A. Bouët and S. Mevel (2008), "Les Accords de partenariat économique. Quels enjeux pour le Sénégal ?", *Revue de l'OFCE*, 107, 65-116.

Bouët, A., Dienesch, E. and C.S. Fall, 2013, What are the expected effects of trade policies on Poverty in Sénégal? a CGE Micro-Macro Analysis: a dual-dual analysis, paper presented at the 16th GTAP conference, Shangha, 2013, June, 12-14.

Bouët, A., Deason, L., and D. Laborde, 2014, Global Trade Patterns, Competitiveness and Growth Outlook, in O. Badiane, T. Makombo and G. Bahiigwa, eds., *Promoting Agricultural Trade to Enhance Resilience in Africa*, ReSSAKS, Annual Trends and Outlook Report, 2013.

Bouët, A., Estrades, C., and D. Laborde, 2013, Households heterogeneity in a global CGE model: an illustration with the MIRAGE-HH (MIRAGE-HouseHolds) model. LAREFI Working Paper CR13EFI01.

Busse, M., A. Borrmann, and H. GroBmann (2004) "The Impact of ACP/EU Economic Partnership Agreements on ECOWAS Countries: An Empirical Analysis of the Trade and Budget Effects", Final Report, Hamburg Institute of International Economics, Hamburg, Germany.

Bourguignon, F. and M. Bussolo, M., 2013, Income Distribution in Computable General Equilibrium Modeling, in P. Dixon and D.W. Jorgenson, eds., *Handbook of Computable General Equilibrium Modeling*, Amsterdam: North Holland.

Bussolo, M., Lay, J., Medvedev, D., van der Mensbrugghe, D. (2008), "A Poverty Assessment Using a Top-down Macro-micro Modeling Framework", In: Bourguignon, F., Bussolo, M., and L.A. Pereira da Silva, eds., 2008, *The Impact of Macroeconomic Policies on Poverty and Income Distribution: Macro-micro Evaluation Techniques and Tools*, Washington: Palgrave MacMilland and The World Bank.

Decaluwé, B, Laborde, D., Maisonnave H. and V., Robichaud, 2008, Regional CGE modeling for West Africa: an EPA Study, Volumes 1, 2, 3, 4. Report for the EC and ECOWAS secretariats.

Decaluwé, B, Laborde, D., Maisonnave H. and V., Robichaud, 2010, Analysis of the Alternative Market Access Scenarios and EPADP for West Africa, Volumes 1, 2, 3.Report for the EC and ECOWAS secretariats. 2010.

Decreux, Y., & Valin, H. (2007). MIRAGE , Updated Version of the Model for Trade Policy Analysis Focus on Agriculture and Dynamics. *CEPII*.

De Vreyer, P., et F., Roubaud, eds, 2013, *Urban Labor Markets in Sub-Saharan Africa*, Agence Francaise de Developpement and The World Bank.

FAO (2013). FAOSTAT. Available Online at < http://faostat.fao.org/>

Femenia, F. (2012). Functional Forms Commonly Used in CGE Models. AGRODEP Technical Note 02. Available Online at <http://www.agrodep.org/resource/functional-forms-commonly-used-cge-models>

Fouré, J., A. Bénassy-Quéré and L. Fontagné (2012), The Great Shift: Macroeconomic Projections for the World Economy at the 2050 Horizon, CEPII Working paper 2012-03. - Available Online at < http://www.cepii.fr/anglaisgraph/bdd/baseline.htm#sthash.LTHY86Pg.dpuf>

Ganuza, E., Paes de Barros, R. and Vos, R., 2002, Labour market adjustment, poverty, and inequality during liberalization, in Vos, R., Paes de Barros, R. and Taylor, L., eds., *Economic Liberalization, Distribution and Poverty. Latin America in the 1990s*, Cheltenham (UK), Northampton (MA): Edward Elgar Publishers, 54-88

ILO (2013) International Labor Organization. Statistics and Databases. Available Online <http://www.ilo.org/global/statistics-and-databases/lang--en/index.htm>

IMF (2013) International Monetary Fund. World Economic Outlook Database. Available Online at <https://www.imf.org/external/pubs/ft/weo/2013/01/weodata/index.aspx>

Karingi, S.N., R. Lang, N. Oulmane, R. Perez, M. Sadni-Jallab and H. Ben Hammouda (2005), "Economic and Welfare Impacts of the EU-Africa Economic Partnership Agreements", African Trade Policy Centre Work in Progress No. 10, Economic Commission for Africa, Addis Ababa.

Keck, A. and R. Piermartini (2008), "The Impact of Economic Partnership Agreements in Countries of the Southern African Development Community", *Journal of African Economies*, 17(1), 85-130.

Laborde, D., Martin, W., & van der Mensbrugghe, D. (2011). Measuring the Impacts of Global Trade Reform with Optimal Aggregators of Distortions. Washington, D.C.

Laborde, D., Robichaud, V., and S. Tokgoz (2013), MIRAGRODEP 1.0: Documentation, AGRODEP Technical Note December.

Lee, H., & Van Der Mensbrugghe, D. (2001). Interactions between Direct Investment and Trade in the Asia-Pacific Region, mimeo.

Milner C., Morrissey O. and McKay A. (2005), "Some simple analytics of the trade and welfare effects of Economic Partnership Agreements", *Journal of African Economies*, 14(3), 327-358.

Narayanan, B. G. and T. L. Walmsley, Editors (2008). Global Trade, Assistance, and Production: The GTAP 7 Data Base, Center for Global Trade Analysis, Purdue University.

Perez, R. (2006), "Are the Economic Partnership Agreements a First-best Optimum for the African Caribbean Pacific Countries?", Journal of World Trade, 40 (6), 999-1019.

Stifel, D., Thorbecke, E., 2003, A dual-dual CGE model of an archetype African economy: Trade reform, migration and poverty, *Journal of Policy Modeling*, 25: 207-235.

Tekere M. and Ndlela D. (2003), "Impact Assessment of Economic Partnership Agreements on Southern African Development Community and Preliminary Adjustment Scenarios, Final Report", Trade and Development Studies Centre, Harare, Zimbabwe.

Vos, R. and V. Sanchez (2010), "A Non-Parametric Microsimulation Approach to Assess Changes in Inequality and Poverty", International Journal of Microsimulation , 3(1): 8-23.

Winters, L.A., 2002, Trade Liberalisation and Poverty: What are the Links?, The World Economy, 25: 1339-1367.

Winters, L.A., McCulloch, N., and A. McKay, 2004, Trade Liberalization and Poverty: the Evidence so far, *Journal of Economic Literature*, XLII, March: 72-115.

7. Annex 1

MIRAGRODEP is a Computable General Equilibrium (CGE) model based on MIRAGE (Modelling International Relations under Applied General Equilibrium). It is a multi-region, multi-sector model, dynamically recursive[7] CGE model. MIRAGE was initially developed at CEPII and is devoted to trade policy analysis. As opposed to a single country CGE model, a multi-country CGE model allows for a detailed and consistent representation of Rest of the World. This way, international economic linkages are captured through the international trade of goods and foreign direct investment (FDI).

This annex presents a complete technical description of the model used in this study. It is based on Laborde, Robichaud and Tokgoz (2013). Specific equations describing the dual-dual hypothesis have been added for this project.

Social Accounting Matrix (SAM) and trade data in MIRAGRODEP is based on GTAP 9 (Narayanan and Walmsley, 2012). The GTAP Data Base is a fully documented global data base which contains complete bilateral trade information, transport and protection linkages among 113 regions for all 57 GTAP commodities for 2004. For MIRAGRODEP, base year is 2007 and outlook period is from 2008 to 2025. Trade policy data comes from MAcMAP-HS6.

1) Model Structure

a) Dimensions and sets

The MIRAGRODEP model distinguishes multiple sectors (or activities, industries) each of them producing one single commodity (or good, product). Sectors and commodities are referred to using indices *i* or *j*, both representing the exact same elements. The subset *Transport* refers to the transportation commodities and sectors.

MIRAGRODEP is a global dynamic model. Each variable is thus indexed in time (index t) and by region using indices r (origin country), s (destination country), *rr* and *ss* corresponding respectively to the same elements.

Set *f* refers to the five (5) factors of production: skilled labor (index *SkLab*), unskilled labor (*UnSkLab*), natural resources (*NatlRes*), capital (*Capital*) and land (*Land*). As will be discussed below, it is assumed that unskilled workers are not perfectly mobile across sectors of production. Hence, sectors are grouped according to the area, rural (*L1*) or urban (*L2*), both elements being included in set *Ltype*.

In the dual-dual version of MIRAGRODEP formal(i,r) is a subset of sectors in each country: it includes all formal sectors while informal(i,r) is its complement and includes all informal sectors. In the developing countries on which this study focuses, *i.e.,* Bénin, Burkina Faso, Côte d'Ivoire, Ghana, Nigeria, Sénégal, Togo and the region "rest of Ecowas"[8], informal sectors have been selected after a

[7] Dynamically recursive models do not include expectation of value of variables in future periods in the model. Plus, value of variable X at the end of period t is the initial value of variable X at the beginning of period t+1.

[8] These eight countries/regions are all the elements of a subset of r, the set of countries and this subset is called r_dual(r).

review of literature[9] and after consideration of the importance of capital and skilled labor in all sectors since informal sectors are not supposed to hire skilled labor and are not supposed to be relatively capitalistic. In those countries of interest, formal sectors are the other sectors while in all other countries all sectors are formal. Table 27 indicates the sector breakdown into formal and informal sectors in West African countries.

Table 19: Formal vs. informal sectors

Informal sectors	Formal sectors	Formal sectors
Vegetables and Fruits	Vegetable Oil	Paper Products
Oilseeds	Other Food	Other Mineral
Other Crops	Textile	Metals
Construction	Wearing Apparel	Capital Goods
Cereals	Leather Product	Utilities
Sugar	Chemicals	Transportation
Cattle	Motor Vehicles	Business Services
Other Animal	Electonics	Other services
Fisheries	Other Industries	Public Services
Red Meat	Other Natural Resources	
White Meat	Fossil Fuel	
Dairy products	Beverage and Tobacco	
Trade	Wood Products	

Table 20: Rural vs. urban sectors

Urban sectors	Urban sectors	Rural sectors
Vegetable Oil	White Meat	Vegetables and Fruits
Other Food	Dairy products	Oilseeds
Textile	Beverage and Tobacco	Other Crops
Wearing Apparel	Wood Products	Cereals
Leather Product	Paper Products	Sugar
Chemicals	Other Mineral	Cattle
Motor Vehicles	Metals	Other Animal
Electonics	Capital Goods	
Other Industries	Utilities	
Construction	Trade	
Other Natural Resources	Transportation	
Fisheries	Business Services	
Fossil Fuel	Other services	
Red Meat	Public Services	

The dual-dual version of MIRAGRODEP makes also a distinction between rural and urban sectors, that is to say economic activities that are supposed to take place in rural and urban areas. This is the basis of

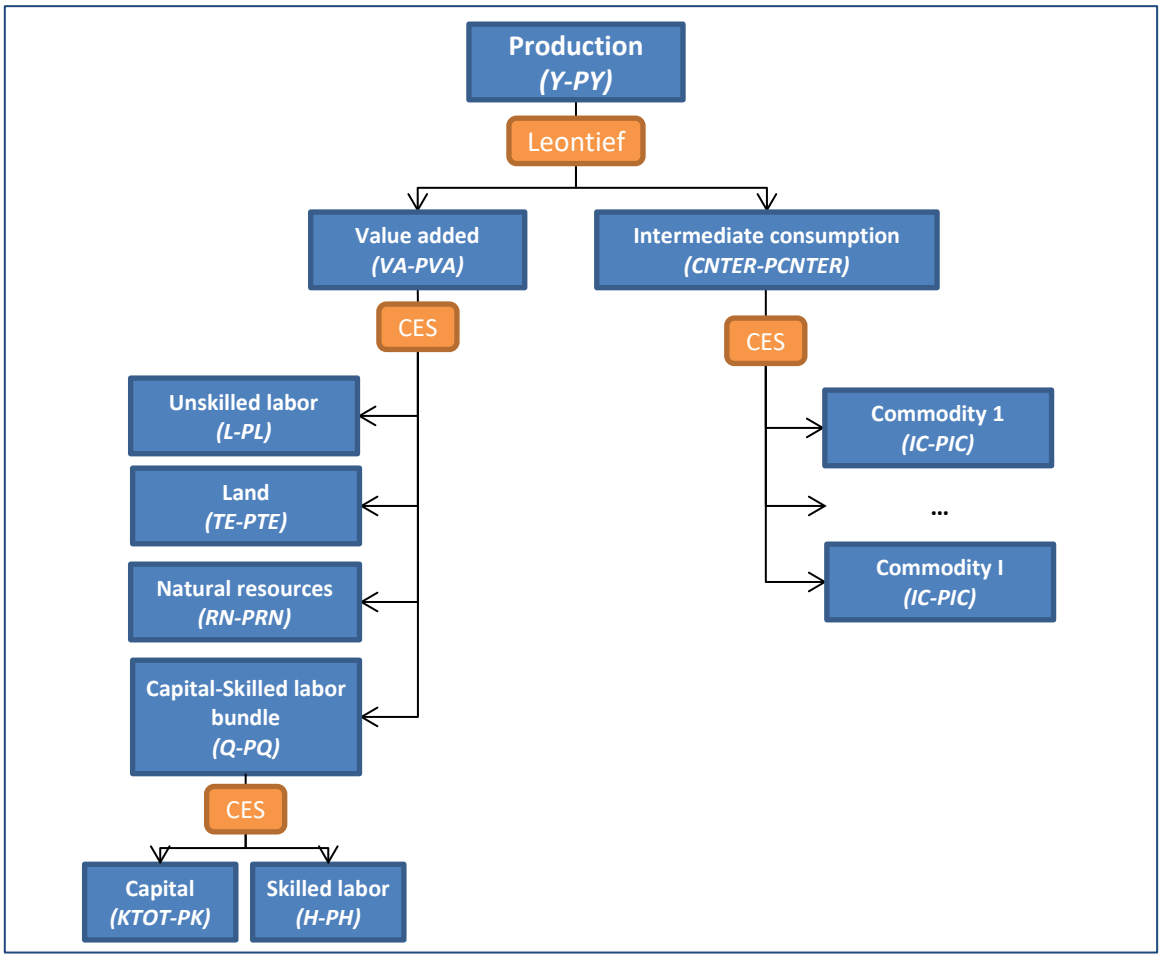
[9] See Benjamin and Mbaye (2012) and de Vreyer and Roubaud (2013).

the modelling of the rural-urban migration. Table 28 indicates the sector decomposition between rural and urban sectors.

2) Production

The production in each sector and in each region follows the nested structure depicted in Figure 1 below. At the top level, total output $Y_{j,r,t}$ is a Leontief of total value added, $VA_{j,r,t}$, and of total intermediate consumption, $CNTER_{j,r,t}$. In other words, there are no substitution possibilities between the two aggregated inputs, they are used in perfect complementarity, and thus their shares in total production are constant.

Figure 1: Nested production function[10]



Note: The acronyms for the volume followed by its corresponding price appear in brackets.

Mathematically:

$$Y_{j,r,t} = a_{j,r}^{VA} \, VA_{j,r,t} \qquad (1)$$

$$Y_{j,r,t} = a_{j,r}^{CNTER} \, CNTER_{j,r,t} \qquad (2)$$

[10] The acronyms for the volume followed by its corresponding price appear in brackets.

with

$a_{j,r}^{VA}$ Value added scale coefficient

$a_{j,r}^{CNTER}$ Total intermediate consumption scale coefficient

Hence, the producer price of output, $PY_{j,r,t}$, is a weighted sum of the price of value added, $PVA_{j,r,t}$, and of that of total intermediate consumption, $PCNTER_{j,r,t}$.

$$PY_{j,r,t}\, Y_{j,r,t} = PVA_{j,r,t}\, VA_{j,r,t} + PCNTER_{j,r,t}\, CNTER_{j,r,t} \quad (3)$$

At the second level, on the value added side, total value added is a combination of unskilled labor, $L_{j,r,t}$, land, $TE_{j,r,t}$, natural resources, $RN_{j,r,t}$, and capital-skilled labor bundle, $Q_{j,r,t}$.[11] It is assumed that these inputs are imperfect substitutes for one another, which is represented through the use of a constant elasticity of substitution (CES) function[12]. The representative firm minimizes its costs subject to the CES aggregator, which yield the following first order conditions:

$$L_{j,r,t} = a_{j,r}^{L}\, VA_{j,r,t}\, PGF_{r,t}{}^{\sigma_j^{VA}-1} \left(\frac{PVA_{j,r,t}}{PL_{j,r,t}}\right)^{\sigma_j^{VA}} \quad (4)$$

$$TE_{j,r,t} = a_{j,r}^{TE} \cdot VA_{j,r,t} \cdot PGF_{r,t}{}^{\sigma_j^{VA}-1} \cdot \left(\frac{PVA_{j,r,t}}{PTE_{j,r,t}}\right)^{\sigma_j^{VA}} \quad (5)$$

$$RN_{j,r,t} = a_{j,r}^{RN} \cdot VA_{j,r,t} \cdot PGF_{r,t}{}^{\sigma_j^{VA}-1} \left(\frac{PVA_{j,r,t}}{PRN_{j,r,t}}\right)^{\sigma_j^{VA}} \quad (6)$$

$$Q_{j,r,t} = a_{j,r}^{Q} \cdot VA_{j,r,t} \cdot PGF_{r,t}{}^{\sigma_j^{VA}-1} \cdot \left(\frac{PVA_{j,r,t}}{PQ_{j,r,t}}\right)^{\sigma_j^{VA}} \quad (7)$$

with

$a_{j,r}^{L}$ Unskilled labor coefficient

$a_{j,r}^{TE}$ Land coefficient

$a_{j,r}^{RN}$ Natural resources coefficient

$a_{j,r}^{Q}$ Capital-skilled labor aggregate coefficient

σ_j^{VA} Value added elasticity

$PGF_{r,t}$ Total factor productivity

[11] It is noteworthy that in informal sectors there is no skilled labor and this bundle is only capital.

[12] It might be worth noting that some parameters are solely indexed in *j*. It is the case, for example, for the elasticity used in the value added functions (σ_j^{VA}). This specification implies that the same parameter is used for all regions, but that it differs from one sector to the other.

It follows that the price of value added is a weighted sum of the price of unskilled labor, $PL_{j,r,t}$ the price of land, $PTE_{j,r,t}$ the price of natural resources, $PRN_{j,r,t}$, and the aggregated price of capital and skilled workers, $PQ_{j,r,t}$ (the price of capital in informal sectors).

$$PVA_{j,r,t}\, VA_{j,r,t} = PL_{j,r,t}\, L_{j,r,t} + PTE_{j,r,t}\, TE_{j,r,t} + PRN_{j,r,t}\, RN_{j,r,t} + PQ_{j,r,t}\, Q_{j,r,t} \qquad (8)$$

The price paid by the producer for each factor differs from the one received by the households by the amount of taxes, which can be negative in the cases where factors are subsidized. The model also distinguishes ad valorem taxes from taxes that are applied on volume. Hence:

$$PL_{j,r,t} = WLt_{Ltype,r,t}\left(1 + taxf^{VAL}_{UnSkLab,j,r,t}\right) + PIndC_{r,t}\, taxf^{VOL}_{UnSkLab,j,r,t} \qquad (9)$$

$$PTE_{j,r,t} = WTE_{j,r,t}\left(1 + taxf^{VAL}_{Land,j,r,t}\right) + PIndC_{r,t}\, taxf^{VOL}_{Land,j,r,t} \qquad (10)$$

$$PRN_{j,r,t} = WRN_{j,r,t}\left(1 + taxf^{VAL}_{NatlRes,j,r,t}\right) + PIndC_{r,t}\, taxf^{VOL}_{NatlRes,j,r,t} \qquad (11)$$

with

$WLt_{ltype,r,t}$	Rate of return to unskilled labor (net of taxes)
$WTE_{j,r,t}$	Rate of return to land (net of taxes)
$WRN_{j,r,t}$	Rate of natural resources (net of taxes)
$PIndC_{r,t}$	Consumer price index
$taxf^{VAL}_{f,j,r,t}$	Rate of factor-based taxes (ad valorem)
$taxf^{VOL}_{f,j,r,t}$	Rate of factor-based taxes (on volume)

In countries r_dual with dual-dual modelling, in the previous equation $WLt_{Ltype,r,t}$ is replaced by $WLurbaninf_{r\_dual,t}$ in urban and informal sectors, by $WLruralinf_{r\_dual,t}$ in rural and informal sectors, by $WLurbanfor_{r\_dual,t}$ in urban and formal sectors, and by $WLruralfor_{r\_dual,t}$ in rural and formal sectors. Consequently in these countries there are four equilibrium rates of return to unskilled labor (net of taxes):

$WLurbaninf_{r\_dual,t}$	Rate of return to unskilled labor in urban informal sectors (net of taxes)
$WLruralinf_{r\_dual,t}$	Rate of return to unskilled labor in rural informal sectors (net of taxes)
$WLurbanfor_{r\_dual,t}$	Rate of return to unskilled labor in urban formal sectors (net of taxes)
$WLruralfor_{r\_dual,t}$	Rate of return to unskilled labor in rural informal sectors (net of taxes)

At the bottom level, for formal sectors on the value added side, capital, $KTOT_{j,r,t}$ and skilled labor, $H_{j,r,t}$, are combined through a CES function, once again to represent the imperfect substitutability between the two factors of production. Minimization of production costs subject to the CES aggregator gives the following demand functions:

$$H_{j,r,t} = a^{H}_{j,r}\, Q_{j,r,t} \left(\frac{PQ_{j,r,t}}{PH_{j,r,t}}\right)^{\sigma^{CAP}_{j}} \quad (12)$$

$$KTOT_{j,r,t} = a^{K}_{j,r}\, Q_{j,r,t} \left(\frac{PQ_{j,r,t}}{PK_{j,r,t}}\right)^{\sigma^{CAP}_{j}} \quad (13)$$

with

$a^{H}_{j,r}$	Skilled labor coefficient
$a^{K}_{j,r}$	Capital coefficient
σ^{CAP}_{j}	Capital-skilled labor elasticity

The price of the capital-skilled labor bundle is thus a weighted sum of the rental rate of capital, $PK_{j,r,t}$, and of the price of skilled labor, $PH_{j,r,t}$.

$$PQ_{j,r,t}\, Q_{j,r,t} = PK_{j,r,t}\, KTOT_{j,r,t} + PH_{j,r,t}\, H_{j,r,t} \quad (14)$$

Again, the prices paid for the factors of production differ from the ones received by households as there are taxes levied on each of them.

$$PH_{j,r,t} = WH_{r,t}\left(1 + taxf^{VAL}_{SkLab,j,r,t}\right) + PIndC_{r,t}\, taxf^{VOL}_{SkLab,j,r,t} \quad (15)$$

$$PK_{j,r,t} = WK_{j,r,t}\left(1 + taxf^{VAL}_{Capital,j,r,t}\right) + PIndC_{r,t}\, taxf^{VOL}_{Capital,j,r,t} \quad (16)$$

with

$WH_{r,t}$	Rate of return to skilled labor (net of taxes)
$WK_{j,r,t}$	Rate of return to capital (net of taxes)

Concerning informal sectors we get: $\forall (i,r) \in informal\ (i,r), KTOT_{i,r,t} = Q_{i,r,t}$ and $PQ_{i,r,t} = PK_{i,r,t}$.

On the intermediate consumption side, the commodities (index i) used in the production process are assumed to be imperfect substitutes. Once again, a CES function is used to represent this imperfect substitutability, and cost minimization yields the demand for each input, $IC_{i,j,r,t}$:

$$IC_{i,j,r,t} = a^{IC}_{i,j,r}\, CNTER_{j,r,t} \left(\frac{PCNTER_{j,r,t}}{PIC_{i,j,r,t}}\right)^{\sigma^{IC}} \quad (17)$$

with

$a^{IC}_{i,j,r}$	Intermediate consumption scale coefficient
σ^{IC}	Intermediate consumption elasticity

The price of total intermediate consumption is a weighted sum of the price paid for each commodity, $PIC_{i,j,r,t}$.

$$PCNTER_{j,r,t}\, CNTER_{j,r,t} = \sum_i PIC_{i,j,r,t}\, IC_{i,j,r,t} \quad (18)$$

The price of each input is subject to taxes, $taxicc_{i,j,r,t}$, and thus differ from the price received by producers $PDEMTOT_{i,r,t}$.

$$PIC_{i,j,r,t} = PDEMTOT_{i,r,t}\left(1 + taxicc_{i,j,r,t}\right) \quad (19)$$

3) Income and savings

a) Households

Households are assumed to be homogenous and they own all factors of production. They, hence, receive all the payments made to factors of production. They also receive transfers from the government, which are indexed to take into account population growth and the evolution of the price index.

$$\begin{aligned} REVH_{r,t} = \sum_{j} \Bigg\{ & WRN_{j,r,t}\, RN_{j,r,t} + WTE_{j,r,t}\, TE_{j,r,t} + WH_{r,t}\, H_{j,r,t} \\ & + \sum_{Ltype} WLt_{Ltype,r,t}\, L_{j,r,t} + \sum_{s} WK_{j,s,t}\, K_{j,r,s,t} \Bigg\} \\ & + Pop^{ag}_{totpop,r,t} TRH_{r,t}\, PIndC_{r,t} \end{aligned} \quad (20)$$

with

$REVH_{r,t}$	Households' income
$TRH_{r,t}$	Public transfers to households
$Pop^{ag}_{totpop,r,t}$	Population

Households savings, $SAVH_{r,t}$, are a fixed proportion epa_r of their income net of direct taxes, $RECDIR_{r,t}$, and the rest of their income is dedicated to consumption budget, $BUDH_{r,t}$.

$$SAVH_{r,t} = epa_r\,(REVH_{r,t} - RECDIR_{r,t}) \quad (21)$$

$$BUDH_{r,t} = REVH_{r,t} - SAVH_{r,t} - RECDIR_{r,t} \quad (22)$$

b) Government

The income of the government, $REVG_{r,t}$, consists of taxes collected on production, $RECPROD_{i,r,t}$, on factors of production, $RECFAC_{i,r,t}$, on exports, $RECEXP_{i,r,t}$, on imports, $RECDD_{i,r,t}$,on consumption, $RECCONS_{i,r,t}$, and households' income, $RECDIR_{r,t}$.

$$\begin{aligned} REVG_{r,t} = \sum_{i} \Big\{ & RECPROD_{i,r,t} + RECFAC_{i,r,t} + RECEXP_{i,r,t} + RECDD_{i,r,t} \\ & + RECCONS_{i,r,t} \Big\} + RECDIR_{r,t} \end{aligned} \quad (23)$$

Taxes on production are collected on the value of output of each activity. It is important to note that tax rates should be considered as *net* rates, that is taxes net of subsidy. Hence, all tax rates can be either positive or negative.

$$RECPROD_{i,r,t} = taxP_{i,r,t}\, PY_{i,r,t}\, Y_{i,r,t} \tag{24}$$

with

$taxP_{i,r,t}$ Production tax rate

Receipt from taxes on factors of production is the sum of volume and value taxes on each factor.

$$\begin{aligned} RECFAC_{j,r,t} = PIndC_{r,t} \big(& taxf^{VOL}_{Land,j,r,t}\, TE_{j,r,t} + taxf^{VOL}_{NatlRes,j,r,t}\, RN_{j,r,t} \\ & + taxf^{VOL}_{SkLab,j,r,t}\, H_{j,r,t} + taxf^{VOL}_{UnSkLab,j,r,t}\, L_{j,r,t} \\ & + taxf^{VOL}_{Capital,j,r,t}\, KTOT_{j,r,t} \big) + taxf^{VAL}_{Land,j,r,t}\, WTE_{j,r,t}\, TE_{j,r,t} \\ & + taxf^{VAL}_{NatlRes,j,r,t}\, WRN_{j,r,t}\, RN_{j,r,t} + taxf^{VAL}_{SkLab,j,r,t}\, WH_{r,t}\, H_{j,r,t} \\ & + taxf^{VAL}_{UnSkLab,j,r,t} \sum_{Ltype} WLt_{Ltype,r,t}\, L_{j,r,t} \\ & + taxf^{VAL}_{Capital,j,r,t}\, WK_{j,r,t}\, KTOT_{j,r,t} \end{aligned} \tag{25}$$

Exports may be subject to three taxes: taxes on production, $taxP_{i,r,t}$, regular taxes on exports, $taxEXP_{i,r,s,t}$, and export tax equivalent of multi-fiber arrangement quota premium, $taxAMF_{i,r,s,t}$.

$$\begin{aligned} RECEXP_{i,r,t} = PY_{i,r,t} \big(& 1 \\ & + taxP_{i,r,t} \big) \sum_{s} \big(taxEXP_{i,r,s,t} + taxAMF_{i,r,s,t} \big) TRADE_{i,r,s,t} \end{aligned} \tag{26}$$

with

$TRADE_{i,r,s,t}$ Exports of commodity *i* from country *r* to country *s*

Duties, $DD_{i,s,r,t}$, are collected on imports evaluated at the CIF price, $PCIF_{i,s,r,t}$.

$$RECDD_{i,r,t} = \sum_{s} DD_{i,s,r,t}\, PCIF_{i,s,r,t}\, TRADE_{i,s,r,t} \tag{27}$$

Taxes are levied on households' consumption, $CH_{i,r,t}$, government current expenditure on goods and services, $CG_{i,r,t}$, on commodities sold for investment purposes, $KG_{i,r,t}$, and on intermediate consumption, $IC_{i,j,r,t}$. Each buyer faces a specific tax rate, respectively , $taxcc_{i,r,t}$, $taxgc_{i,r,t}$, $taxkgc_{i,r,t}$, and $taxicc_{i,j,r,t}$.

$$\begin{aligned} RECCONS_{i,r,t} = PDEMTOT_{i,r,t} \Big\{ & taxcc_{i,r,t}\, CH_{i,r,t} + taxgc_{i,r,t}\, CG_{i,r,t} \\ & + taxkgc_{i,r,t}\, KG_{i,r,t} + \sum\nolimits_{j} taxicc_{i,j,r,t}\; IC_{i,j,r,t} \Big\} \end{aligned} \tag{28}$$

Finally, the government collects direct taxes on households' income:

$$RECDIR_{r,t} = taxdir_{r,t}\ REVH_{r,t} \quad (29)$$

Government savings, $SAVG_{r,t}$, are assumed to be a fixed proportion, $PUBSOLD_r$, of GDP at market prices, $GDPMP_{r,t}$. Finally, the budget allocated to public current expenditure on goods and services, $BUDG_{r,t}$, is determined residually.

$$SAVG_{r,t} = PUBSOLD_r\ GDPMP_{r,t} \quad (30)$$

$$BUDG_{r,t} = REVG_{r,t} - SAVG_{r,t} - Pop^{ag}_{totpop,r,t}\ TRH_{r,t}\ PIndC_{r,t} \quad (31)$$

4) Demand

Domestic absorption of each commodity, $DEMTOT_{i,r,t}$, is the sum of consumer demand, $CH_{i,r,t}$, demand from public administrations, $CG_{i,r,t}$, intermediate demand, $IC_{i,j,r,t}$, and demand for investment purposes, $KG_{i,r,t}$.

$$DEMTOT_{i,r,t} = CH_{i,r,t} + CG_{i,r,t} + \sum_j IC_{i,j,r,t} + KG_{i,r,t} \quad (32)$$

a) Private demand

Households' demand is characterized by a LES-CES (Linear Expenditure System - Constant Elasticity of Substitution) specification. This specific utility function allows the evolution of the demand structure of each region to be accounted for as its income level changes. Additionally, the elasticity of substitution is constant only among the sectoral consumptions over and above a minimum level. The minimal level of consumption can vary across region (e.g. developing versus developed country).

$$CH_{i,r,t} = Pop^{ag}_{totpop,r,t} \left(cmin_{i,r} + a^C_{i,r}\ AUX_{r,t} \left(\frac{P_{r,t}}{PC_{i,r,t}} \right)^{\sigma^C_r} \right) \quad (33)$$

with

$cmin_{i,r}$	Minimal consumption of commodity i (per capita)
$a^C_{i,r}$	Household consumption coefficient
$AUX_{r,t}$	Utility
$P_{r,t}$	Shadow price of utility
$PC_{i,r,t}$	Price of final private consumption
σ^C_r	Households' consumption elasticity of substitution

Households maximize their utility subject to their consumption budget, $BUDH_{r,t}$, from which one can derive the shadow price of utility, $P_{r,t}$.

$$BUDH_{r,t} = \sum_i PC_{i,r,t}\, CH_{i,r,t} \tag{34}$$

$$P_{r,t}\, AUX_{r,t} = \sum_i PC_{i,r,t} \left(\frac{CH_{i,r,t}}{Pop^{ag}_{totpop,r,t}} - cmin_{i,r} \right) \tag{35}$$

The price paid by household for each commodity, $PC_{i,r,t}$, differs from the one received by the suppliers, $PDEMTOT_{i,r,t}$, by the amount of taxes collected, $taxcc_{i,r,t}$.

$$PC_{i,r,t} = PDEMTOT_{i,r,t}\, (1 + taxcc_{i,r,t}) \tag{36}$$

Finally, the consumer price index, $PIndC_{r,t}$, is a Fisher index.

$$PindC_{r,t} = \sqrt{\left[\frac{\sum_i PC_{i,r,t}\, CH^O_{i,r}}{\sum_i PC^O_{i,r}\, CH^O_{i,r}}\right] \left[\frac{\sum_i PC_{i,r,t}\, CH_{i,r,t}}{\sum_i PC^O_{i,r}\, CH_{i,r,t}}\right]} \tag{37}$$

with

$CH^O_{i,r}$ Benchmark value of households' consumption

$PC^O_{i,r}$ Benchmark value of final private consumption

b) Public demand

Government spending on each commodity is a fixed share, $\alpha^G_{i,r}$, of total public expenditure in goods and services, $BUDG_{r,t}$, and government purchases are subject to taxes, $taxgc_{i,r,t}$.

$$PCG_{i,r,t}\, CG_{i,r,t} = \alpha^G_{i,r}\, BUDG_{r,t} \tag{38}$$

$$PCG_{i,r,t} = PDEMTOT_{i,r,t}\, (1 + taxgc_{i,r,t}) \tag{39}$$

with

$PCG_{i,r,t}$ Price of final public consumption

c) Demand for investment purposes

Finally, demand for investment purposes, $KG_{i,r,t}$, is characterized by a CES function. Cost minimization subject to the CES aggregator yields the following demand function:

$$KG_{i,r,t} = a^{KG}_{i,r}\, INVTOT_{r,t} \left(\frac{PINVTOT_{r,t}}{PKG_{i,r,t}} \right)^{\sigma^{KG}} \tag{40}$$

with

$a_{i,r}^{KG}$ Capital good scale coefficient

$INVTOT_{r,t}$ Total investment

$PINVTOT_{r,t}$ Price of investment

$PKG_{i,r,t}$ Price of capital good consumption

σ^{KG} Capital good elasticity

The aggregated price of capital, $PINVTOT_{r,t}$, is thus a weighted sum of the price paid for each commodity, $PKG_{i,r,t}$.

$$PINVTOT_{r,t}\ INVTOT_{r,t} = \sum_{i} PKG_{i,r,t}\ KG_{i,r,t} \qquad (41)$$

Again, the price paid by the purchaser differs from the one received by the seller, as taxes apply.

$$PKG_{i,r,t} = PDEMTOT_{i,r,t}\ (1 + taxkgc_{i,r,t}) \qquad (42)$$

d) Demand by geographic origin

MIRAGRODEP is a bilateral trade model consistent with the Armington assumption: commodities are assumed to be heterogeneous according to their origin, and thus, imperfect substitutes for one another (Armington 1969). Nested CES functions are used to reflect preferences among varieties originating from different countries. Therefore, countries can export and import the same product at the same time due to consumer preferences for different varieties. The price transmission between domestic and international market is imperfect and highly dependent on the choice of the CES trade elasticities and the initial share of trade.

At the top level, total demand, $DEMTOT_{i,r,t}$, combines aggregated imports, $M_{i,r,t}$, and local production, $D_{i,r,t}$, through a CES function. From cost minimization subject to the CES aggregator, the following demand functions can be derived:

$$D_{i,r,t} = a_{i,r}^{D}\ DEMTOT_{i,r,t} \left(\frac{PDEMTOT_{i,r,t}}{PD_{i,r,t}}\right)^{\sigma_i^{ARM}} \qquad (43)$$

$$M_{i,r,t} = a_{i,r}^{M}\ DEMTOT_{i,r,t} \left(\frac{PDEMTOT_{i,r,t}}{PM_{i,r,t}}\right)^{\sigma_i^{ARM}} \qquad (44)$$

with

$a_{i,r}^{D}$ Local demand scale coefficient

$a_{i,r}^{M}$ Total import demand scale coefficient

σ_i^{ARM} Armington elasticity

$PD_{i,r,t}$ Price of demand for domestic commodity

$PM_{i,r,t}$ Aggregated price of imports

Consequently, the price of the aggregated commodity, $PDEMTOT_{i,r,t}$, is a weighted sum of aggregated imports, $PM_{i,r,t}$, and of the price of the domestically produced commodity, $PD_{i,r,t}$, which differs from the amount received by the producer, $PY_{i,r,t}$, since taxes, $taxP_{i,r,t}$, apply.

$$PDEMTOT_{i,r,t}\ DEMTOT_{i,r,t} = PD_{i,r,t}\ D_{i,r,t} + PM_{i,r,t}\ M_{i,r,t} \quad (45)$$

$$PD_{i,r,t} = PY_{i,r,t}\ (1 + taxP_{i,r,t}) \quad (46)$$

At the second level, total imports, $M_{i,r,t}$, are a CES combination of imports from the different trading partners, $DEMA_{i,s,r,t}$. Cost minimization under the CES aggregation constraint leads to the following demand function:

$$DEMA_{i,s,r,t} = a_{i,s,r}^{IMP}\ M_{i,r,t} \left(\frac{PM_{i,r,t}}{PDEMA_{i,s,r,t}}\right)^{\sigma_i^{IMP}} \quad (47)$$

with

$a_{i,s,r}^{IMP}$ Import demand scale coefficient

σ_i^{IMP} Import elasticity

$PDEMA_{i,s,r,t}$ Price of bilateral trade

This specification implies that the price of aggregated imports is a weighted sum of the price paid to the different partners. The price paid by the purchaser differs from the CIF price as import duties, $DD_{i,s,r,t}^{A}$, apply.

$$PM_{i,r,t}\ M_{i,r,t} = \sum_{s} PDEMA_{i,s,r,t}\ DEMA_{i,s,r,t} \quad (48)$$

$$PDEMA_{i,s,r,t} = PCIF_{i,s,r,t}\ \left(1 + DD_{i,s,r,t}^{A}\right) \quad (49)$$

And the CIF price is determined by the production costs, on which taxes apply, plus the transportation costs.

$$PCIF_{i,s,r,t} = PY_{i,s,t}\ \left(1 + taxEXP_{i,s,r,t} + taxAMF_{i,s,r,t}\right)\left(1 + taxP_{i,s,t}\right) + MUO_{i,s,r}\ PTr_{i,s,r,t} \quad (50)$$

with

$Ptr_{i,s,r,t}$ Price of transportation per commodity exported

$MUO_{i,s,r}$ Transport coefficient

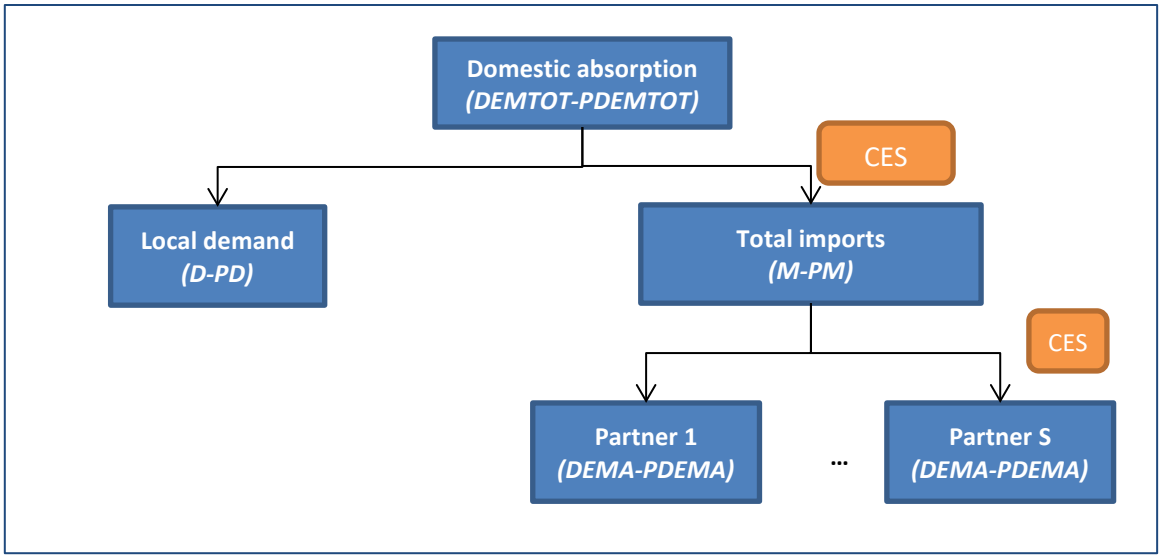
Following the consistent aggregator methodology as defined in(Laborde, Martin, and van der Mensbrugghe, 2011), aggregation of volumes differ whether they are estimated at world prices or at domestic prices. Hence, the shadow price of bilateral trade, $PDEM_{i,s,r,t}$, is evaluated as follow:

$$PDEM_{i,s,r,t} = PCIF_{i,s,r,t}\left(1 + DD_{i,s,r,t}\right) \quad (51)$$

which leads to the definition of the aggregator $TRADE_{i,s,r,t}$:

$$DEMA_{i,s,r,t}\, PDEMA_{i,s,r,t} = PDEM_{i,s,r,t}\, TRADE_{i,s,r,t} \quad (52)$$

Figure 2: Demand by geographic origin[13]



e) Demand for transportation services

The volume of transportation $Tr_{i,s,r,t}$ required to move commodity i imported by region r from region s is a fixed proportion $MUO_{i,s,r}$ of total imports $TRADE_{i,s,r,t}$.

$$Tr_{i,s,r,t} = MUO_{i,s,r}\, TRADE_{i,s,r,t} \quad (53)$$

Transportation demand per mode, $TrMode_{Transport,i,s,r,t}$, is then determined as being a fixed share $a^{Tr}_{Transport,i,s,r}$ of total transportation demand. Implicitly, thus, total demand for transportation is a Cobb-Douglas type of function. Hence, the exact price formulation for the aggregated price of transportation, $PTr_{i,s,r,t}$, is the dual form of a Cobb-Douglas.

$$PTrMode_{Transport,t}\, TrMode_{Transport,i,s,r,t} = a^{Tr}_{Transport,i,s,r,t}\, Tr_{i,s,r,t}\, PTr_{i,s,r,t} \quad (54)$$

$$PTr_{i,s,r,t} = \prod_{Transport} PTrMode_{Transport,t}^{a^{Tr}_{Transport,i,s,r}} \quad (55)$$

with

[13] The acronyms for the volume followed by its corresponding price appear in brackets.

$PTrMode_{Transport,t}$ Price of transport per mode

$PTr_{i,r,s,t}$ Price of transportation by commodity and partners

5) Supply and market clearing

a) Transportation market

The world supply of transportation services per mode, $WorldTr_{Transport,t}$, follows a Cobb-Douglas specification. It follows that the supply from each region, $TrSupply_{Transport,r,t}$, is a constant share of the world value of transportation.

$$WorldTr_{Transport,t} = c^{T}_{Transport} \prod_{r} TrSupply_{Transport,r,t}^{a^{TrSupply}_{Transport,r}} \quad (56)$$

$$PY_{Transport,r,t}\left(1 + taxP_{Transport,r,t}\right) TrSupply_{Transport,r,t} = a^{TrSupply}_{Transport,r}\, PTrMode_{Transport,t}\, WorldTr_{Transport,t} \quad (57)$$

with

$c^{T}_{Transport}$ Scale coefficient

$a^{TrSupply}_{Transport,r}$ Share of each region in the world transport production

Market for transportation clears, since demand of transportation is equal to supply. Equilibrium on the transportation market determines the world prices of transportation per mode, $PTrMode_{Transport,t}$.

$$WorldTr_{Transport,t} = \sum_{i,r,s} TrMode_{Transport,i,r,s,t} \quad (58)$$

b) Commodity market

In each region, supply of each commodity is equal to demand. Market clearing determines the price of each commodity, $PY_{i,r,t}$.

$$Y_{i,r,t} = D_{i,r,t} + \sum_{s} TRADE_{i,r,s,t} + TrSupply_{i,r,t} \quad (59)$$

c) Factors of production market

- Labor market

Total supply of skilled workers, $\overline{H}_{r,t}$, is fixed and grows exogenously. Skilled workers are assumed to be perfectly mobile across formal sectors and there is no unemployment. Hence, the equilibrium between supply and demand determines the wage rate.

$$\overline{H}_{r,t} = \sum_{(j,r)\in formal(j,r)} H_{j,r,t} \quad (60)$$

In countries with dual-dual modelling, skilled workers are only employed in formal sectors but amid formal sectors they may decide to migrate to urban or rural sectors. Skilled workers get better salaries in urban areas. There may be different explanations of this prevailing gap. One is that everything else being equal there is a preference for living in rural areas. Another one is the existence of a monopolistic union which determines urban wages of skilled workers in formal urban sectors by maximization of its utility which depends on the number of the union's members and the level of salary given to its members: this results in a salary higher than the one that would prevail without a monopolistic union. Consequently four equations determine the levels of wages and employment for skilled labor in countries with Dual-Dual modelling. If r is a country with Dual-Dual modelling we have:

$$WHu_{r,t} = WHr_{r,t}(1 + gap_{h_r}) \quad (61)$$

$$Hu_{r,t} + Hr_{r,t} = \overline{H}_{r,t} \quad (62)$$

$$Hu_{r,t} = \sum_{i\in urban(i,r)} H_{i,r} \quad (63)$$

$$Hr_{r,t} = \sum_{i\in rural(i,r)} H_{i,r} \quad (64)$$

With

$WHu_{r,t}$ the remuneration of skilled labor in urban sectors in country r at time t;

$WHr_{r,t}$ the remuneration of skilled labor in rural sectors in country r at time t;

$gap_{h_r}$is a constant positive parameter;

$Hu_{r,t}$is the total demand for skilled labor in urban sectors in country r at time t;

$Hr_{r,t}$is the total demand for skilled labor in rural sectors in country r at time t;

$\overline{H}_{r,t}$ is the total supply of skilled labor in country r at time t.

Regarding unskilled workers ($\overline{L}_{r,t}$), total supply is exogenous and grows at an exogenous rate.

In countries without dual-dual modelling, it is assumed that unskilled workers cannot move freely between rural and urban areas. A CET (Constant elasticity of transformation) is used to characterize the regional supply of unskilled workers. Unskilled workers maximize their income subject to the CET aggregator, which leads to the following supply function:

$$Lt_{Ltype,r,t} = b^{Lt}_{Ltype,r}\, \overline{L}_{r,t} \left(\frac{WLt_{Ltype,r,t}}{\overline{WL}_{r,t}}\right)^{\sigma^L} \quad (65)$$

with

$Lt_{Ltype,r,t}$	Labor supply on the Ltype market
$b^{Lt}_{Ltype,r}$	Labor scale coefficient
$\overline{WL}_{r,t}$	Aggregated wage for unskilled workers
σ^{L}	Labor elasticity

It follows that the aggregated wage for unskilled workers $\overline{WL}_{r,t}$ is a weighted sum of the wages received on each market:

$$\overline{WL}_{r,t}\,\bar{L}_{r,t} = \sum_{Ltype} WLt_{Ltype,r,t}\,Lt_{Ltype,r,t} \qquad (66)$$

which is determined by the equilibrium between supply and demand.

$$Lt_{Ltype,r,t} = \sum_{j} L_{j,r,t} \qquad (67)$$

In countries with dual-dual modelling, for unskilled workers, wages are lower in informal sectors than in formal sectors. There are different explanations of this gap: minimum wages, transaction costs, higher productivity in formal sectors due to capital intensive process of production. According to which these are urban or rural sectors, this gap may differ. The mobility of unskilled labor between rural and urban areas is ruled by an equation of migration: migration stops when the salary in formal rural sectors, $WLr\_formal_{r,t}$ is equal to the expected salary that can be obtained in urban areas where either an unskilled worker works in urban formal sector (probability $\text{Prob\_Lu\_formal}_{r,t}$ and gets a salary of $WLu\_formal_{r,t}$, or he works in a urban informal sector (probability $1 - \text{Prob\_Lu\_formal}_{r,t}$) and gets a salary of $WLu\_informal_{r,t}$. This probability is function of the share of the urban formal employment of unskilled labor $\text{Lu\_formal}_{r.t}$ in total employment of unskilled labor in urban sectors: $Lu_{r,t}$. Consequently there are eleven equations describing this double segmentation of the employment of unskilled labor in countries with dual-dual modelling:

$$WLr\_formal_{r,t} = Prob\_Lu\_formal_{r,t} WLu\_formal_{r,t} + [1 - Prob\_Lu\_formal_{r,t}]WLu\_informal_{r,t} \qquad (68)$$

$$Prob\_Lu\_formal_{r,t} = cp_r \frac{Lu\_formal_{r.t}}{Lu\_informal_{r.t} + Lu\_formal_{r,t}} \qquad (69)$$

$$Lu_{r,t} + Lr_{r,t} = \bar{L}_{r,t} \qquad (70)$$

$$Lu\_formal_{r,t} + Lu\_informal_{r.t} = Lu_{r,t} \qquad (71)$$

$$Lr\_formal_{r,t} + Lr\_informal_{r.t} = Lr_{r,t} \qquad (72)$$

$$Lu\_formal_{r,t} = \sum_{formal(i,r)} Lu_{i.r,t} \quad (73)$$

$$Lu\_informal_{r,t} = \sum_{informal(i,r)} Lu_{i.r,t} \quad (74)$$

$$Lr\_formal_{r,t} = \sum_{formal(i,r)} Lr_{i.r,t} \quad (75)$$

$$Lr\_informal_{r,t} = \sum_{informal(i,r)} Lr_{i.r,t} \quad (76)$$

$$WLu\_formal_{r,t} = WLu\_informal_{r,t}(1 + \delta u_r) \quad (77)$$

$$WLr\_formal_{r,t} = WLr\_informal_{r,t}(1 + \delta r_r) \quad (78)$$

With:

cp_r a positive constant;

Lu_informal$_{r.t}$: urban informal employment of unskilled labor;

$Lr_{r,t}$: total employment of unskilled labor in rural sectors;

Lu_informal$_{r,t}$: total demand for unskilled labor in urban informal sectors in country r at time t;

Lu_formal$_{r,t}$: total demand for unskilled labor in urban formal sectors in country r at time t;

Lr_informal$_{r,t}$: total demand for unskilled labor in rural informal sectors in country r at time t;

Lr_formal$_{r,t}$: total demand for unskilled labor in rural formal sectors in country r at time t;

$WLr\_informal_{r,t}$: the remuneration of unskilled labor in rural informal sectors in country r at time t;

δu_r: a positive constant;

δr_r: a positive constant.

- Land market

Land mobility across sectors is assumed to be imperfect. Land supply, $\overline{TE}_{r,t}$, behaves as an isoelastic function of the real return to land (Lee and Mensbrugghe, 2001). This implies that the greater the real overall return to land, the greater will be the overall supply of land.

$$\overline{TE}_{r,t} = \overline{TE}_r^0 \left(\frac{\overline{WTE}_{r,t}}{P_{r,t}}\right)^{\sigma_r^{TE}} \quad (79)$$

with

$\overline{\overline{TE}}_r^0$ Benchmark value of total land supply

$\overline{\overline{WTE}}_{r,t}$ Aggregated price for land

σ_r^{TE} Total land supply elasticity

To represent the imperfect mobility of land, supply to each activity, $TE_{j,r,t}$, is determined following a CET aggregation. Land owners maximize their income subject to the CET aggregator, which leads to the following first order condition:

$$TE_{j,r,t} = b_{j,r}^{TE}\ \overline{\overline{TE}}_{r,t}\ \left(\frac{WTE_{j,r,t}}{\overline{\overline{WTE}}_{r,t}}\right)^{\sigma^{TE}} \qquad (80)$$

with

$b_{j,r}^{TE}$ Land scale coefficient

σ^{TE} Land elasticity

It follows that the aggregated price of land is weighted sum of the price received in each activity.

$$\overline{\overline{WTE}}_{r,t}\ \overline{\overline{TE}}_{r,t} = \sum_j WTE_{j,r,t}\ TE_{j,r,t} \qquad (81)$$

- *Capital market*

At each period, the capital stock invested by region *s* in activity *j* in region *r*, $K_{j,s,r,t}$, is given by the depreciated stock of capital inherited from the preceding period plus new investment $INV_{j,s,r,t}$

$$K_{j,s,r,t} = K_{j,s,r,t-1}(1-\delta_r) + INV_{j,s,r,t} \qquad (82)$$

with

δ_r Depreciation rate

Where the investment per activity and region of destination depends on the rate of return to capital, the aggregated price of new capital and capital stock[14].

$$INV_{j,s,r,t} = B_{s,t}\ a_{j,s,r}\ KTOT_{j,r,t}\ e^{\alpha\left(\frac{WK_{j,r,t}}{PINVTOT_{r,t}}\right)} \qquad (83)$$

with

$B_{s,t}$ Scale coefficient for investment

$a_{j,s,r}$ Investment scale coefficient

α Elasticity of investment to return on capital

[14] For a complete discussion on the investment behaviour, see Decreux and Valin (2007).

Total investment made in region r, $INVTOT_{r,t}$, is simply the sum of investment made in each sector of each region:

$$INVTOT_{r,t} = \sum_{j,s} INV_{j,s,r,t} \quad (84)$$

In each sector, total supply of capital equals demand, which determines the rate of return to capital specific to this sector ($WK_{i,r,t}$).

$$KTOT_{i,r,t} = \sum_{s} K_{i,s,r,t} \quad (85)$$

6) Macroeconomic constraints

In each region, total investment must be equal to total savings:

$$SAVH_{r,t} + SAVG_{r,t} - CAB_{r,t} = \sum_{i,s} PINVTOT_{s,t}\, INV_{i,r,s,t} \quad (86)$$

Where $CAB_{r,t}$ represents the current account balance, which is a constant share $SOLD_{r,t}$ of world GDP, $PIBMVAL_t$.

$$CAB_{r,t} = PIBMVAL_t\, SOLD_{r,t} \quad (87)$$

World GDP is the simply the sum of regional GDPs, $GDPMR_{r,t}$:

$$PIBMVAL_t = \sum_{r} GDPMP_{r,t} \quad (88)$$

Consistent with the system of national accounting, each region's GDP at market prices is given by the sum of payments to factors of production and of indirect taxes.

$$GDPMP_{r,t} = \sum_{j} PVA_{j,r,t}\, VA_{j,r,t} + \sum_{i} \{RECPROD_{i,r,t} + RECEXP_{i,r,t} + RECDD_{i,r,t} + RECCONS_{i,r,t}\} \quad (89)$$

Finally, real GDP, $GDPVOL_{r,t}$, is computed by dividing GDP at market prices by a consumer price index:

$$GDPVOL_{r,t} = \frac{GDPMP_{r,t}}{\prod_i PC_{i,r,t}\, pondC_{i,r}} \quad (90)$$

7) Economic Closures

In MIRAGRODEP, every economic agent balances income and expenditures: income of households equals to spending of households (consumption, savings and transfers), firms' spending (including

payment to capital) equals firms' revenue. At a global level, savings must be equal to investment. At the country level, a gap between the two variables can occur due to international capital movements. Nevertheless, constraints on current account surplus or deficits are also considered, leading to real exchange rate adjustments (determining relative international prices among economies). Furthermore, supply equals demand for all commodities and factors in the economy.

8) Summary of Model Structure

Table 21: Equations of MIRAGRODEP

Production		
First level: Leontief		GAMS
1.	$Y_{j,r,t} = a_{j,r}^{VA}\, VA_{j,r,t}$	EQ_VA
2.	$Y_{j,r,t} = a_{j,r}^{CNTER}\, CNTER_{j,r,t}$	EQ_CNTER
3.	$PY_{j,r,t}\, Y_{j,r,t} = PVA_{j,r,t}\, VA_{j,r,t} + PCNTER_{j,r,t}\, CNTER_{j,r,t}$	EQ_Y
Second level – Value added: CES		GAMS
4.	$L_{j,r,t} = a_{j,r}^{L}\, VA_{j,r,t}\, PGF_{r,t}{}^{\sigma_j^{VA}-1} \left(\frac{PVA_{j,r,t}}{PL_{j,r,t}}\right)^{\sigma_j^{VA}}$	EQ_CES_L
5.	$TE_{j,r,t} = a_{j,r}^{TE} \cdot VA_{j,r,t} \cdot PGF_{r,t}{}^{\sigma_j^{VA}-1} \cdot \left(\frac{PVA_{j,r,t}}{PTE_{j,r,t}}\right)^{\sigma_j^{VA}}$	EQ_CES_TE
6.	$RN_{j,r,t} = a_{j,r}^{RN} \cdot VA_{j,r,t} \cdot PGF_{r,t}{}^{\sigma_j^{VA}-1} \left(\frac{PVA_{j,r,t}}{PRN_{j,r,t}}\right)^{\sigma_j^{VA}}$	EQ_CES_RN
7.	$Q_{j,r,t} = a_{j,r}^{Q} \cdot VA_{j,r,t} \cdot PGF_{r,t}{}^{\sigma_j^{VA}-1} \cdot \left(\frac{PVA_{j,r,t}}{PQ_{j,r,t}}\right)^{\sigma_j^{VA}}$	EQ_CES_Q
8.	$PVA_{j,r,t}\, VA_{j,r,t} = PL_{j,r,t}\, L_{j,r,t} + PTE_{j,r,t}\, TE_{j,r,t} + PRN_{j,r,t}\, RN_{j,r,t} + PQ_{j,r,t}\, Q_{j,r,t}$	EQ_CES_PVA
9.	$PL_{j,r,t} = WLt_{Ltype,r,t}\left(1 + taxf_{UnSkLab,j,r,t}^{VAL}\right) + PIndC_{r,t}\, taxf_{UnSkLab,j,r,t}^{VOL}$	EQ_PL
10.	$PTE_{j,r,t} = WTE_{j,r,t}\left(1 + taxf_{Land,j,r,t}^{VAL}\right) + PIndC_{r,t}\, taxf_{Land,j,r,t}^{VOL}$	EQ_PTE
11.	$PRN_{j,r,t} = WRN_{j,r,t}\left(1 + taxf_{NatlRes,j,r,t}^{VAL}\right) + PIndC_{r,t}\, taxf_{NatlRes,j,r,t}^{VOL}$	EQ_PRN

Third level – Capital-Skilled labor bundle: CES		GAMS
12.	$$H_{j,r,t} = a_{j,r}^{H}\, Q_{j,r,t} \left(\frac{PQ_{j,r,t}}{PH_{j,r,t}}\right)^{\sigma_j^{CAP}}$$ With $H_{j,r,t} = Q_{j,r,t}$ in formal sectors in countries with dual-dual modelling and $H_{j,r,t} = 0$ in informal sectors in countries with dual-dual modelling.	EQ_H
13.	$$KTOT_{j,r,t} = a_{j,r}^{K}\, Q_{j,r,t} \left(\frac{PQ_{j,r,t}}{PK_{j,r,t}}\right)^{\sigma_j^{CAP}}$$	EQ_KTOT
14.	$$PQ_{j,r,t}\, Q_{j,r,t} = PK_{j,r,t}\, KTOT_{j,r,t} + PH_{j,r,t}\, H_{j,r,t}$$ With: $PQ_{j,r,t} = PH_{j,r,t}$ in countries with dual-dual modelling	EQ_PQ
15.	$$PH_{j,r,t} = WH_{r,t}\left(1 + taxf_{SkLab,j,r,t}^{VAL}\right) + PIndC_{r,t}\, taxf_{SkLab,j,r,t}^{VOL}$$	EQ_PH
16.	$$PK_{j,r,t} = WK_{j,r,t}\left(1 + taxf_{Capital,j,r,t}^{VAL}\right) + PIndC_{r,t}\, taxf_{Capital,j,r,t}^{VOL}$$	EQ_PK
Second level – Intermediate consumption: CES		GAMS
17.	$$IC_{i,j,r,t} = a_{i,j,r}^{IC}\, CNTER_{j,r,t} \left(\frac{PCNTER_{j,r,t}}{PIC_{i,j,r,t}}\right)^{\sigma^{IC}}$$	EQ_IC
18.	$$PCNTER_{j,r,t}\, CNTER_{j,r,t} = \sum_i PIC_{i,j,r,t}\, IC_{i,j,r,t}$$	EQ_PCNTER
19.	$$PIC_{i,j,r,t} = PDEMTOT_{i,r,t}\left(1 + taxicc_{i,j,r,t}\right)$$	EQ_PIC
Income and Savings		
Households		GAMS

20.	$$REVH_{r,t} = \sum_{j} \Big\{ WRN_{j,r,t}\, RN_{j,r,t} + WTE_{j,r,t}\, TE_{j,r,t} + WH_{r,t}\, H_{j,r,t} + \sum_{Ltype} WLt_{Ltype,r,t}\, L_{j,r,t} + \sum_{s} WK_{j,s,t}\, K_{j,r,s,t} \Big\} + Pop^{ag}_{totpop,r,t} TRH_{r,t}\, PIndC_{r,t}$$	EQ_REVH
21.	$$SAVH_{r,t} = epa_r\, (REVH_{r,t} - RECDIR_{r,t})$$	EQ_SAVH
22.	$$BUDH_{r,t} = REVH_{r,t} - SAVH_{r,t} - RECDIR_{r,t}$$	EQ_BUDH
Government		**GAMS**
23.	$$REVG_{r,t} = \sum_{i} \{RECPROD_{i,r,t} + RECFAC_{i,r,t} + RECEXP_{i,r,t} + RECDD_{i,r,t} + RECCONS_{i,r,t}\} + RECDIR_{r,t}$$	EQ_REVG
24.	$$RECPROD_{i,r,t} = taxP_{i,r,t}\, PY_{i,r,t}\, Y_{i,r,t}$$	EQ_RECPROD
25.	$$RECFAC_{j,r,t} = PIndC_{r,t} \left(taxf^{VOL}_{Land,j,r,t}\, TE_{j,r,t} + taxf^{VOL}_{NatlRes,j,r,t}\, RN_{j,r,t} + taxf^{VOL}_{SkLab,j,r,t}\, H_{j,r,t} + taxf^{VOL}_{UnSkLab,j,r,t}\, L_{j,r,t} + taxf^{VOL}_{Capital,j,r,t}\, KTOT_{j,r,t}\right) + taxf^{VAL}_{Land,j,r,t}\, WTE_{j,r,t}\, TE_{j,r,t} + taxf^{VAL}_{NatlRes,j,r,t}\, WRN_{j,r,t}\, RN_{j,r,t} + taxf^{VAL}_{SkLab,j,r,t}\, WH_{r,t}\, H_{j,r,t} + taxf^{VAL}_{UnSkLab,j,r,t} \sum_{Ltype} WLt_{Ltype,r,t}\, L_{j,r,t} + taxf^{VAL}_{Capital,j,r,t}\, WK_{j,r,t}\, KTOT_{j,r,t}$$	EQ_RECFAC

26.	$$RECEXP_{i,r,t} = PY_{i,r,t}\,(1 + taxP_{i,r,t}) \sum_{s} (taxEXP_{i,r,s,t} + taxAMF_{i,r,s,t}) TRADE_{i,r,s,t}$$	EQ_RECEXP
27.	$$RECDD_{i,r,t} = \sum_{s} DD_{i,s,r,t}\; PCIF_{i,s,r,t}\; TRADE_{i,s,r,t}$$	EQ_RECDD
28.	$$RECCONS_{i,r,t} = PDEMTOT_{i,r,t} \left\{ taxcc_{i,r,t}\; CH_{i,r,t} + taxgc_{i,r,t}\; CG_{i,r,t} + taxkgc_{i,r,t}\; KG_{i,r,t} + \sum_{j} taxicc_{i,j,r,t}\; IC_{i,j,r,t} \right\}$$	EQ_RECCONS
29.	$$RECDIR_{r,t} = taxdir_{r,t}\; REVH_{r,t}$$	EQ_RECDIR
30.	$$SAVG_{r,t} = PUBSOLD_{r}\; GDPMP_{r,t}$$	EQ_SAVG
31.	$$BUDG_{r,t} = REVG_{r,t} - SAVG_{r,t} - Pop^{ag}_{totpop,r,t}\; TRH_{r,t}\; PIndC_{r,t}$$	EQ_BUDG
Demand		
32.	$$DEMTOT_{i,r,t} = CH_{i,r,t} + CG_{i,r,t} + \sum_{j} IC_{i,j,r,t} + KG_{i,r,t}$$	EQ_DEMTOT
Private demand		GAMS
33.	$$CH_{i,r,t} = Pop^{ag}_{totpop,r,t} \left(cmin_{i,r} + a^{C}_{i,r}\; AUX_{r,t} \left(\frac{P_{r,t}}{PC_{i,r,t}} \right)^{\sigma^{C}_{r}} \right)$$	EQ_CH
34.	$$BUDH_{r,t} = \sum_{i} PC_{i,r,t}\; CH_{i,r,t}$$	EQ_AUX
35.	$$P_{r,t}\; AUX_{r,t} = \sum_{i} PC_{i,r,t} \left(\frac{CH_{i,r,t}}{Pop^{ag}_{totpop,r,t}} - cmin_{i,r} \right)$$	EQ_P

36.	$PC_{i,r,t} = PDEMTOT_{i,r,t}\,(1 + taxcc_{i,r,t})$	EQ_PC
37.	$PindC_{r,t} = \sqrt{\left[\frac{\sum_i PC_{i,r,t}\,CH^O_{i,r}}{\sum_i PC^O_{i,r}\,CH^O_{i,r}}\right]\left[\frac{\sum_i PC_{i,r,t}\,CH_{i,r,t}}{\sum_i PC^O_{i,r}\,CH_{i,r,t}}\right]}$	EQ_PI
Public demand		GAMS
38.	$PCG_{i,r,t}\,CG_{i,r,t} = \alpha^G_{i,r}\,BUDG_{r,t}$	EQ_CG
39.	$PCG_{i,r,t} = PDEMTOT_{i,r,t}\left(1 + taxgc_{i,r,t}\right)$	EQ_PCG
Demand for investment purposes		GAMS
40.	$KG_{i,r,t} = a^{KG}_{i,r}\,INVTOT_{r,t}\left(\frac{PINVTOT_{r,t}}{PKG_{i,r,t}}\right)^{\sigma^{KG}}$	EQ_KG
41.	$PINVTOT_{r,t}\,INVTOT_{r,t} = \sum_i PKG_{i,r,t}\,KG_{i,r,t}$	EQ_PINVTOT
42.	$PKG_{i,r,t} = PDEMTOT_{i,r,t}\,(1 + taxkgc_{i,r,t})$	EQ_PKG
Demand by geographic origin		GAMS
43.	$D_{i,r,t} = a^D_{i,r}\,DEMTOT_{i,r,t}\left(\frac{PDEMTOT_{i,r,t}}{PD_{i,r,t}}\right)^{\sigma^{ARM}_i}$	EQ_D
44.	$M_{i,r,t} = a^M_{i,r}\,DEMTOT_{i,r,t}\left(\frac{PDEMTOT_{i,r,t}}{PM_{i,r,t}}\right)^{\sigma^{ARM}_i}$	EQ_M
45.	$PDEMTOT_{i,r,t}\,DEMTOT_{i,r,t} = PD_{i,r,t}\,D_{i,r,t} + PM_{i,r,t}\,M_{i,r,t}$	EQ_PDEMTOT
46.	$PD_{i,r,t} = PY_{i,r,t}\,(1 + taxP_{i,r,t})$	EQ_PD
47.	$DEMA_{i,s,r,t} = a^{IMP}_{i,s,r}\,M_{i,r,t}\left(\frac{PM_{i,r,t}}{PDEMA_{i,s,r,t}}\right)^{\sigma^{IMP}_i}$	EQ_DEMA
48.	$PM_{i,r,t}\,M_{i,r,t} = \sum_s PDEMA_{i,s,r,t}\,DEMA_{i,s,r,t}$	EQ_PM
49.	$PDEMA_{i,s,r,t} = PCIF_{i,s,r,t}\left(1 + DD^A_{i,s,r,t}\right)$	EQ_PDEMA

50.	$PCIF_{i,s,r,t} = PY_{i,s,t}\left(1 + taxEXP_{i,s,r,t} + taxAMF_{i,s,r,t}\right)\left(1 + taxP_{i,s,t}\right) + MUO_{i,s,r}\, PTr_{i,s,r,t}$	EQ_PCIF
51.	$PDEM_{i,s,r,t} = PCIF_{i,s,r,t}\left(1 + DD_{i,s,r,t}\right)$	EQ_PDEM
52.	$DEMA_{i,s,r,t}\, PDEMA_{i,s,r,t} = PDEM_{i,s,r,t}\, TRADE_{i,s,r,t}$	EQ_TRADE
Demand for transportation services		GAMS
53.	$Tr_{i,s,r,t} = MUO_{i,s,r}\, TRADE_{i,s,r,t}$	EQ_Tr
54.	$PTrMode_{Transport,t}\, TrMode_{Transport,i,s,r,t} = a^{Tr}_{Transport,i,s,r,t}\, Tr_{i,s,r,t}\, PTr_{i,s,r,t}$	EQ_TrMode
55.	$PTr_{i,s,r,t} = \prod_{Transport} PTrMode^{a^{Tr}_{Transport,i,s,r}}_{Transport,t}$	EQ_PTr
Supply and market clearing		
Transportation market		GAMS
56.	$WorldTr_{Transport,t} = c^{T}_{Transport} \prod_{r} TrSupply^{a^{TrSupply}_{Transport,r}}_{Transport,r,t}$	EQ_WorldTr
57.	$PY_{Transport,r,t}\left(1 + taxP_{Transport,r,t}\right) TrSupply_{Transport,r,t} = a^{TrSupply}_{Transport,r}\, PTrMode_{Transport,t}\, WorldTr_{Transport,t}$	EQ_TrSupply
58.	$WorldTr_{Transport,t} = \sum_{i,r,s} TrMode_{Transport,i,r,s,t}$	EQ_PTrMode
Commodity market		GAMS
59.	$Y_{i,r,t} = D_{i,r,t} + \sum_{s} TRADE_{i,r,s,t} + TrSupply_{i,r,t}$	EQ_PY
Factors of production market		
Labor market		GAMS
60.	$\bar{H}_{r,t} = \sum_{j} H_{j,r,t}$	EQ_WH

61.	$WHu_{r,t} = WHr_{r,t}(1 + gap_{h_r})$	EQ_WHu
62.	$Hu_{r,t} + Hr_{r,t} = \bar{H}_{r,t}$	EQ_WHr
63.	$Hu_{r,t} = \sum_{i \in urban(i,r)} H_{i,r}$	EQ_Hu
64.	$Hr_{r,t} = \sum_{i \in rural(i,r)} H_{i,r}$	EQ_Hr
65.	$Lt_{Ltype,r,t} = b^{Lt}_{Ltype,r}\, \bar{L}_{r,t} \left(\frac{WLt_{Ltype,r,t}}{\overline{WL}_{r,t}}\right)^{\sigma^L}$	EQ_CET_Lt
66.	$\overline{WL}_{r,t}\, \bar{L}_{r,t} = \sum_{Ltype} WLt_{Ltype,r,t}\, Lt_{Ltype,r,t}$	EQ_CET_WLbar
67.	$Lt_{Ltype,r,t} = \sum_{j} L_{j,r,t}$	EQ_WLt
68.	$WLr\_formal_{r,t} = Prob\_Lu\_formal_{r,t} WLu\_formal_{r,t} + [1 - Prob\_Lu\_formal_{r,t}] WLu\_informal_{r,t}$	EQ_Lr_formal
69.	$Prob\_Lu\_formal_{r,t} = cp_r \frac{Lu\_formal_{r.t}}{Lu\_informal_{r.t} + Lu\_formal_{r,t}}$	EQ_Prob_Lu_formal
70.	$Lu_{r,t} + Lr_{r,t} = \bar{L}_{r,t}$	EQ_Lu
71.	$Lu\_formal_{r,t} + Lu\_informal_{r.t} = Lu_{r,t}$	EQ_WLu_formal
72.	$Lr\_formal_{r,t} + Lr\_informal_{r.t} = Lr_{r,t}$	EQ_WLr_formal
73.	$Lu\_formal_{r,t} = \sum_{formal(i,r)} Lu_{i.r,t}$	EQ_Lu_formal
74.	$Lu\_informal_{r,t} = \sum_{informal(i,r)} Lu_{i.r,t}$	EQ_Lu_informal

75.	$Lr\_formal_{r,t} = \sum_{formal(i,r)} Lr_{i.r,t}$	EQ_Lr_formal
76.	$Lr\_informal_{r,t} = \sum_{informal(i,r)} Lr_{i.r,t}$	EQ_Lr_informal
77.	$WLu\_formal_{r,t} = WLu\_informal_{r,t}(1 + \delta u_r)$	EQ_WLu_informal
78.	$WLr\_formal_{r,t} = WLr\_informal_{r,t}(1 + \delta r_r)$	EQ_WLr_informal
Land market		GAMS
79.	$\overline{TE}_{r,t} = \overline{TE}_r^O \left(\frac{\overline{WTE}_{r,t}}{P_{r,t}}\right)^{\sigma_r^{\overline{TE}}}$	EQ_TEbar
80.	$TE_{j,r,t} = b_{j,r}^{TE}\, \overline{TE}_{r,t} \left(\frac{WTE_{j,r,t}}{\overline{WTE}_{r,t}}\right)^{\sigma^{TE}}$	EQ_CET_WTE
81.	$\overline{WTE}_{r,t}\, \overline{TE}_{r,t} = \sum_j WTE_{j,r,t}\, TE_{j,r,t}$	EQ_CET_WTEbar
Capital market		GAMS
82.	$K_{j,s,r,t} = K_{j,s,r,t-1}(1 - \delta_r) + INV_{j,s,r,t}$	EQ_K
83.	$INV_{j,s,r,t} = B_{s,t}\, a_{j,s,r}\, KTOT_{j,r,t}\, e^{\alpha\left(\frac{WK_{j,r,t}}{PINVTOT_{r,t}}\right)}$	EQ_INV
84.	$INVTOT_{r,t} = \sum_{j,s} INV_{j,s,r,t}$	EQ_INVTOT
85.	$KTOT_{i,r,t} = \sum_s K_{i,s,r,t}$	EQ_WK
Macroeconomic constraints		
86.	$SAVH_{r,t} + SAVG_{r,t} - CAB_{r,t} = \sum_{i,s} PINVTOT_{s,t}\, INV_{i,r,s,t}$	EQ_B
87.	$CAB_{r,t} = PIBMVAL_t\, SOLD_{r,t}$	EQ_CAB
88.	$PIBMVAL_t = \sum_r GDPMP_{r,t}$	EQ_PIBMVAL

89.	$$GDPMP_{r,t} = \sum_{j} PVA_{j,r,t}\, VA_{j,r,t} + \sum_{i} \{RECPROD_{i,r,t} + RECEXP_{i,r,t} + RECDD_{i,r,t} + RECCONS_{i,r,t}\}$$	EQ_GDP
90.	$$GDPVOL_{r,t} = \frac{GDPMP_{r,t}}{\prod_i PC_{i,r,t}\, pondC_{i,r}}$$	EQ_PGF

Table 22: Variables of MIRAGRODEP

Variable	Definition	GAMS
$AUX_{r,t}$	Utility	AUX(r,Temps,simul)
$B_{r,t}$	Investment scale coefficient	B(r,Temps,simul)
$BUDG_{r,t}$	Budget allocated to public consumption	BUDG(r,Temps,simul)
$BUDH_{r,t}$	Budget allocated to private consumption	BUDH(r,Temps,simul)
$CAB_{r,t}$	Current account balance	CAB(r,temps,simul)
$CGi_{i,r,t}$	Public consumption of commodity *i*	CG(i,r,Temps,simul)
$CH_{i,r,t}$	Consumption of commodity *i* by households	CH(i,r,Temps,simul)
$CNTER_{j,r,t}$	Aggregate intermediate consumption by sector *j*	CNTER(j,r,Temps,simul)
$D_{i,r,t}$	Demand for domestic commodity *i*	D(i,r,Temps,simul)
$DEMA_{i,r,s,t}$	Bilateral trade from *r* to *s* (volume)	DEMA(i,r,s,Temps,simul)
$DEMTOT_{i,r,t}$	Total demand for composite commodity *i*	DEMTOT(i,r,Temps,simul)
$GDPMP_{r,t}$	Gross domestic product at market prices (nominal)	GDPMP(r,Temps,simul)
$GDPVOL_{r,t}$	Gross domestic product at market prices (real)	GDPVOL(r,Temps,simul)
$H_{j,r,t}$	Demand for skilled labor by sector	H(j,r,Temps,simul)
$\bar{H}_{r,t}$	Total skilled labor supply	Hbar(r,Temps,simul)
$IC_{i,j,r,t}$	Intermediate consumption of good *i* by sector *j*	IC(i,j,r,Temps,simul)
$INV_{j,s,r,t}$	Investment made by *s* in sector *j* of region *r*	INV(j,s,r,Temps,simul)
$INVTOT_{r,t}$	Total investment in region *r*	INVTOT(r,Temps,simul)
$K_{j,s,r,t}$	Capital stock invested by *s* in *r*	K(j,s,r,Temps,simul)
$KG_{i,r,t}$	Demand of good *i* for investment purposes	KG(i,r,Temps,simul)
$KTOT_{j,r,t}$	Capital stock available in sector *j*	KTOT(j,r,Temps,simul)
$L_{j,r,t}$	Demand for unskilled labor by sector *j*	L(j,r,Temps,simul)
$\bar{L}_{r,t}$	Total supply of unskilled labor	Lbar(r,Temps,simul)
$Lt_{Ltype,r,t}$	Supply of unskilled labor per type	Lt(Ltype,r,Temps,simul)
$M_{i,r,t}$	Aggregate imports by region *r*	M(i,r,Temps,simul)
$P_{r,t}$	Price of utility	P(r,Temps,simul)
$PC_{i,r,t}$	Price of final private consumption	PC(i,r,Temps,simul)
$PCG_{i,r,t}$	Price of final public consumption	PCG(i,r,Temps,simul)
$PCIF_{i,r,s,t}$	CIF price	PCIF(i,r,s,Temps,simul)
$PCNTER_{j,r,t}$	Price of aggregate intermediate consumption by sector *j*	PCNTER(j,r,Temps,simul)
$PD_{i,r,t}$	Price of for domestic good *i* (including taxes)	PD(i,r,Temps,simul)

$PDEM_{i,r,s,t}$	Price of bilateral trade from *r* to *s*	`PDEM(i,r,s,Temps,simul)`
$PDEMA_{i,r,s,t}$	Price of bilateral trade from *r* to *s*	`PDEMA(i,r,s,Temps,simul)`
$PDEMTOT_{i,r,t}$	Price of composite commodity *i*	`PDEMTOT(i,r,Temps,simul)`
$PGF_{r,t}$	Total factor productivity	`PGF(r,Temps,simul)`
$PH_{j,r,t}$	Price of skilled labor (including taxes)	`PH(j,r,Temps,simul)`
$PIBMVAL_t$	World gross domestic product (value)	`PIBMVAL(Temps,simul)`
$PIC_{i,j,r,t}$	Price of intermediate consumption good *i* for sector *j* (including taxes)	`PIC(i,j,r,Temps,simul)`
$PIndC_{r,t}$	Consumer price index	`PIndC(r,Temps,simul)`
$PINVTOT_{r,t}$	Aggregate price of investment in region *r*	`PINVTOT(r,Temps,simul)`
$PK_{j,r,t}$	Price of capital (including taxes)	`PK(j,r,Temps,simul)`
$PKG_{i,r,t}$	Price of capital good consumption of good i (including taxes)	`PKG(i,r,Temps,simul)`
$PL_{j,r,t}$	Price of unskilled labor (including taxes)	`PL(j,r,Temps,simul)`
$PM_{i,r,t}$	Price of aggregate imports	`PM(i,r,Temps,simul)`
$PQ_{j,r,t}$	Price of capital - skilled labor aggregate	`PQ(j,r,Temps,simul)`
$PRN_{j,r,t}$	Price of natural resources (including taxes)	`PRN(j,r,Temps,simul)`
$PTE_{j,r,t}$	Price of land (including taxes)	`PTE(j,r,Temps,simul)`
$PTr_{i,r,s,t}$	Price of aggregate transport by export	`PTr(i,r,s,Temps,simul)`
$PTrMode_{j,t}$	World price of transport per mode	`PTrMode(j,Temps,simul)`
$PVA_{j,r,t}$	Price of value added	`PVA(j,r,Temps,simul)`
$PY_{j,r,t}$	Output price	`PY(j,r,Temps,simul)`
$Q_{j,r,t}$	Capital - skilled labor aggregate	`Q(j,r,Temps,simul)`
$RECCONS_{i,r,t}$	Consumption tax receipts	`RECCONS(i,r,Temps,simul)`
$RECDD_{i,r,t}$	Tariff revenues	`RECDD(i,r,Temps,simul)`
$RECDIR_{r,t}$	Tax receipts from direct taxation	`RECDIR(r,Temps,simul)`
$RECEXP_{i,r,t}$	Export tax receipts	`RECEXP(i,r,Temps,simul)`
$RECFAC_{j,r,t}$	Receipts from taxes on factors of production	`RECFAC(j,r,Temps,simul)`
$RECPROD_{i,r,t}$	Production tax receipts	`RECPROD(i,r,Temps,simul)`
$REVG_{r,t}$	Government total income	`REVG(r,Temps,simul)`
$REVH_{r,t}$	Households income	`REVH(r,Temps,simul)`
$RN_{j,r,t}$	Demand for natural resources by sector	`RN(j,r,Temps,simul)`
$SAVG_{r,t}$	Government savings	`SAVG(r,Temps,simul)`
$SAVH_{r,t}$	Households savings	`SAVH(r,Temps,simul)`
$SOLD_{r,t}$	Initial share of current account balance in world GDP	`SOLD(r,Temps,simul)`

$TE_{j,r,t}$	Land used in sector *j*	`TE(j,r,Temps,simul)`
$\overline{TE}_{r,t}$	Total land supply	`TEbar(r,Temps,simul)`
$Tr_{i,r,s,t}$	Transport demand by export	`Tr(i,r,s,Temps,simul)`
$TRADE_{i,r,s,t}$	Bilateral trade from *r* to *s* (volume)	`TRADE(i,r,s,Temps,simul)`
$TRH_{r,t}$	Public transfers to households	`TRH(r,Temps,simul)`
$TrMode_{j,i,r,s,t}$	Transport demand by export, per mode	`TrMode(j,i,r,s,Temps,simul)`
$TrSupply_{j,r,t}$	Supply of international transportation by region *r*	`TrSupply(j,r,Temps,simul)`
$VA_{j,r,t}$	Value added	`VA(j,r,Temps,simul)`
$WH_{r,t}$	Rate of return to skilled labor	`WH(r,Temps,simul)`
$WK_{i,r,t}$	Rate of return to capital	`WK(i,r,Temps,simul)`
$\overline{WL}_{r,t}$	Price of aggregate unskilled labor	`WLbar(r,Temps,simul)`
$WLt_{Ltype,r,t}$	Rate of return to unskilled labor	`WLt(Ltype,r,Temps,simul)`
$WorldTr_{j,t}$	World supply of international transportation	`WorldTr(j,Temps,simul)`
$WRN_{j,r,t}$	Rate of return to natural resources	`WRN(j,r,Temps,simul)`
$WTE_{j,r,t}$	Rate of return to land	`WTE(j,r,Temps,simul)`
$\overline{WTE}_{r,t}$	Aggregate price of land	`WTEbar(r,Temps,simul)`
$Y_{j,r,t}$	Total output of sector *j*	`Y(j,r,Temps,simul)`
$WHu_{r,t}$	Remuneration of Skilled labor in urban sectors in country r (a country with dual-dual modelling)	`WHu(r,Temps, simul)`
$WHr_{r,t}$	Remuneration of Skilled labor in rural sectors in country r (a country with dual-dual modelling)	`WHr(r,Temps, simul)`
$Hu_{r,t}$	Total demand of skilled labor by urban sectors in country r (a country with dual-dual modelling)	`Hu(r,Temps, simul)`
$Hr_{r,t}$	Total demand of skilled labor by rural sectors in country r (a country with dual-dual modelling)	`Hr(r,Temps, simul)`
$WLr\_formal_{r,t}$	Remuneration of unskilled labor in formal rural sectors in country r (a country with dual-dual modelling)	`W_Lr_formal(r,Temps, simul)`
$WLu\_formal_{r,t}$	Remuneration of unskilled labor in formal urban sectors in country r (a country with dual-dual modelling)	`W_Lu_formal(r,Temps, simul)`
$WLu\_informal_{r,t}$	Remuneration of unskilled labor in informal urban sectors in country r (a country with dual-dual modelling)	`W_Lu_informal(r,Temps, simul)`
$WLr\_informal_{r,t}$	Remuneration of unskilled labor in informal rural sectors in country r (a country with dual-dual modelling)	`W_Lr_informal(r,Temps, simul)`
$Prob\_Lu\_formal_{r,t}$	Probability of being hired in a formal sector when a unskilled worker has migrated to a urban area in country r (a country with dual-dual modelling)	`Prob_Lu_formal(r,Temps, simul)`

$Lr\_informal_{r,t}$	Total demand for unskilled labor by informal rural sectors in country r (a country with dual-dual modelling)	`Lr_informal(r,Temps, simul)`
$Lr\_formal_{r,t}$	Total demand for unskilled labor by formal rural sectors in country r (a country with dual-dual modelling)	`Lr_formal(r,Temps, simul)`
$Lu\_informal_{r,t}$	Total demand for unskilled labor by informal urban sectors in country r (a country with dual-dual modelling)	`Lu_informal(r,Temps, simul)`
$Lu\_formal_{r,t}$	Total demand for unskilled labor by formal urban sectors in country r (a country with dual-dual modelling)	`Lu_formal(r,Temps, simul)`
$Lu_{r,t}$	Total demand for unskilled labor by urban sectors in country r (a country with dual-dual modelling)	`Lu(r,Temps, simul)`
$Lr_{r,t}$	Total demand for unskilled labor by rural sectors in country r (a country with dual-dual modelling)	`Lr(r,Temps, simul)`

8. Annex 2: Geographical disaggregation and correspondence with GTAP regions

Code MIRAGRODEP	Label
ROW	Rest of the world
ASIA	Asia
NAFTA	NAFTA
LAC	Latin America
CARICOM	CARICOM
E28	European Union
CIS	Community of Independant States
MENA	Middle East and North Africa
Nigeria	Nigeria
Sénégal	Sénégal
Bénin	Bénin
Burkina	Burkina Faso
CotedIvoire	Côte d'Ivoire
Ghana	Ghana
RECOWAS	Rest of ECOWAS
Togo	Togo
RAFRICA	Rest of Africa

GTAP Code	Label	Code MIRAGRODEP
AUS	Australia	ROW
NZL	New Zealand	ROW
XOC	Rest of Oceania	ROW
CHN	China	ASIA
HKG	Hong Kong	ASIA
JPN	Japan	ASIA
KOR	Korea	ASIA
TWN	Taiwan	ASIA
XEA	Rest of East Asia	ASIA
KHM	Cambodia	ASIA
IDN	Indonesia	ASIA
LAO	Laos	ASIA
MYS	Malaysia	ASIA
PHL	Philippines	ASIA
SGP	Singapore	ASIA
THA	Thailand	ASIA
VNM	Viet Nam	ASIA
XSE	Rest of Southeast Asia	ASIA
BGD	Bangladesh	ASIA
IND	India	ASIA
PAK	Pakistan	ASIA
LKA	Sri Lanka	ASIA
NPL	Nepal	ASIA

XSA	Rest of South Asia	ASIA
CAN	Canada	NAFTA
USA	United States of America	NAFTA
MEX	Mexico	NAFTA
XNA	Rest of North America	NAFTA
ARG	Argentina	LAC
BOL	Bolivia	LAC
BRA	Brazil	LAC
CHL	Chile	LAC
COL	Colombia	LAC
ECU	Ecuador	LAC
PRY	Paraguay	LAC
PER	Peru	LAC
URY	Uruguay	LAC
VEN	Venezuela	LAC
XSM	Rest of South America	LAC
CRI	Costa Rica	LAC
GTM	Guatemala	LAC
NIC	Nicaragua	LAC
PAN	Panama	LAC
SLV	El Salvador	LAC
HND	Honduras	LAC
XCA	Rest of Central America	LAC
DOM	Dominican Republic	CARICOM
JAM	Jamaica	CARICOM
PRI	Puerto Rico	CARICOM
TTO	Trinidad and Tobago	CARICOM
XCB	Rest of the Caribbean	CARICOM
AUT	Austria	E28
BEL	Belgium	E28
CYP	Cyprus	E28
CZE	Czech Republic	E28
DNK	Denmark	E28
EST	Estonia	E28
FIN	Finland	E28
FRA	France	E28
DEU	Germany	E28
GRC	Greece	E28
HUN	Hungary	E28
IRL	Ireland	E28
ITA	Italy	E28
LVA	Latvia	E28
LTU	Lithuania	E28
LUX	Luxembourg	E28
MLT	Malta	E28
NLD	Netherlands	E28

POL	Poland	E28
PRT	Portugal	E28
SVK	Slovakia	E28
SVN	Slovenia	E28
ESP	Spain	E28
SWE	Sweden	E28
GBR	United Kingdom	E28
CHE	Switzerland	ROW
NOR	Norway	ROW
XEF	Rest of EFTA	ROW
ALB	Albania	CIS
BGR	Bulgaria	E28
BLR	Belarus	CIS
HRV	Croatia	E28
ROU	Romania	E28
RUS	Russian Federation	CIS
UKR	Ukraine	CIS
XEE	Rest of Eastern Europe	CIS
XER	Rest of Europe	CIS
KAZ	Kazakhstan	CIS
KGZ	Kyrgyztan	CIS
MNG	Mongolia	CIS
XSU	Rest of Former Soviet Union	CIS
ARM	Armenia	CIS
AZE	Azerbaijan	CIS
GEO	Georgia	CIS
IRN	Iran, Islamic Republic of	MENA
TUR	Turkey	MENA
ISR	Israel	MENA
JOR	Jordania	MENA
ARE	United Arab Emirates	MENA
BHR	Bahrain	MENA
KWT	Kuwait	MENA
OMN	Oman	MENA
QAT	Qatar	MENA
SAU	Saudi Arabia	MENA
XWS	Rest of Western Asia	MENA
EGY	Egypt	MENA
MAR	Morocco	MENA
TUN	Tunisia	MENA
XNF	Rest of North Africa	MENA
NGA	Nigeria	Nigeria
SEN	Sénégal	Sénégal
BEN	Bénin	Bénin
BFA	Burkina Faso	Burkina
CIV	Côte d'Ivoire	CotedIvoire

GHA	Ghana	Ghana
GIN	Guinea	RECOWAS
TGO	Togo	Togo
XWF	Rest of Western Africa	RECOWAS
CMR	Cameroon	RAFRICA
XCF	Central Africa	RAFRICA
XAC	South Central Africa	RAFRICA
ETH	Ethiopia	RAFRICA
KEN	Kenya	RAFRICA
MDG	Madagascar	RAFRICA
MWI	Malawi	RAFRICA
MUS	Mauritius	RAFRICA
MOZ	Mozambique	RAFRICA
RWA	Rwanda	RAFRICA
TZA	Tanzania	RAFRICA
UGA	Uganda	RAFRICA
ZMB	Zambia	RAFRICA
ZWE	Zimbabwe	RAFRICA
XEC	Rest of Eastern Africa	RAFRICA
BWA	Botswana	RAFRICA
ZAF	South Africa	RAFRICA
NAM	Namibia	RAFRICA
XSC	Rest of South African Customs Union	RAFRICA
XTW	Rest of the World	ROW

9. Annex 3: Sectoral disaggregation and correspondence with GTAP sectors

Code MIRAGRODEP	Label
v_f	Vegetables and Fruits
osd	Oilseeds
pfb	Plant Fibers
ocr	Other Crops
vol	Vegetable Oil
ofd	Other Food
tex	Textile
wap	Wearing Apparel
lea	Leather Product
crp	Chemicals
mvh	Motor Vehicles
ele	Electronics
omf	Other Industries
cns	Construction
rice	Rice
cereals	Cereals
sug	Sugar
cattle	Cattle
otherAni	Other Animal Products
onr	Other Natural Resources
fish	Fisheries
ffl	Fossil Fuel
meatc	Red Meat
meato	White Meat
dairy	Dairy products
bevtob	Beverage and Tobacco
woodp	Wood Products
paper	Paper Products
mat	Other Mineral
metals	Metals
cgd	Capital Goods
utilities	Utilities
trade	Trade
trans	Transportation
privser	Business Services
otherserv	Other services
pubserv	Public Services

GTAP Code	Label	MIRAGRODEP Code
pdr	Paddy rice	rice
wht	Wheat	cereals
gro	Cereal grains nec	cereals
v_f	Vegetables. fruit. nuts	v_f
osd	Oil seeds	osd
c_b	Sugar cane. sugar beet	sug
pfb	Plant-based fibers	pfb
ocr	Crops nec	ocr
ctl	Cattle.sheep.goats.horses	cattle
oap	Animal products nec	otherAni
rmk	Raw milk	cattle
wol	Wool. silk-worm cocoons	otherAni
frs	Forestry	onr
fsh	Fishing	fish
coa	Coal	ffl
oil	Oil	ffl
gas	Gas	ffl
omn	Minerals nec	onr
cmt	Meat: cattle.sheep.goats.horse	meatc
omt	Meat products nec	meato
vol	Vegetable oils and fats	vol
mil	Dairy products	dairy
pcr	Processed rice	rice
sgr	Sugar	sug
ofd	Food products nec	ofd
b_t	Beverages and tobacco products	bevtob
tex	Textiles	tex
wap	Wearing apparel	wap
lea	Leather products	lea
lum	Wood products	woodp
ppp	Paper products. publishing	paper
p_c	Petroleum. coal products	ffl
crp	Chemical.rubber.plastic prods	crp
nmm	Mineral products nec	mat
i_s	Ferrous metals	metals
nfm	Metals nec	metals
fmp	Metal products	metals
mvh	Motor vehicles and parts	mvh
otn	Transport equipment nec	cgd
ele	Electronic equipment	ele
ome	Machinery and equipment nec	cgd
omf	Manufactures nec	omf
ely	Electricity	utilities
gdt	Gas manufacture. distribution	utilities
wtr	Water	utilities

cns	Construction	cns
trd	Trade	trade
otp	Transport nec	trans
wtp	Sea transport	trans
atp	Air transport	trans
cmn	Communication	privser
ofi	Financial services nec	privser
isr	Insurance	privser
obs	Business services nec	privser
ros	Recreation and other services	otherserv
osg	PubAdmin/Defence/Health/Educat	pubserv
dwe	Dwellings	otherserv