A Computable General Equilibrium Analysis for Haiti

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A Computable General Equilibrium Analysis for Haiti

Martín Cicowiez[1] and Agustín Filippo[2]

1. Introduction

In this document we consider various scenarios related to changes in policies and exogenous conditions; our purpose is to assess various vulnerabilities and opportunities for Haiti. The analytical work leading to the identification of those scenarios included: the analysis of Haiti's economic and social trajectories since the sixties, "Growth diagnostics" methods, and techniques for the discovery of "development gaps" and key drivers of productivity. In terms of method, the simulation analysis in this document is based on a recursive dynamic computable general equilibrium model designed for medium- to long-run development strategy analysis. Results from the CGE model scenarios are passed on to a microsimulation model that relies on household survey data to assess effects on poverty and inequality. More specifically, in four sets simulations, which cover the period FY 2013-2030, we address counterfactual scenarios related to the government and the country's institutional capacity, production and productive sectors, human development, and macroeconomic shocks.

In outline, we proceed as follows. Section 2 describes the Macro-Micro (CGE-Microsimulations) model used in this study together with the data used for implementing them. Section 3 presents the various sets of simulations. In turn, companion documents (i.e., one for each set of simulations) analyze their results. Finally, we provide some concluding remarks in Section 4. Appendix A provides additional detail regarding the computable general equilibrium model developed for this study.

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2. Method and Data

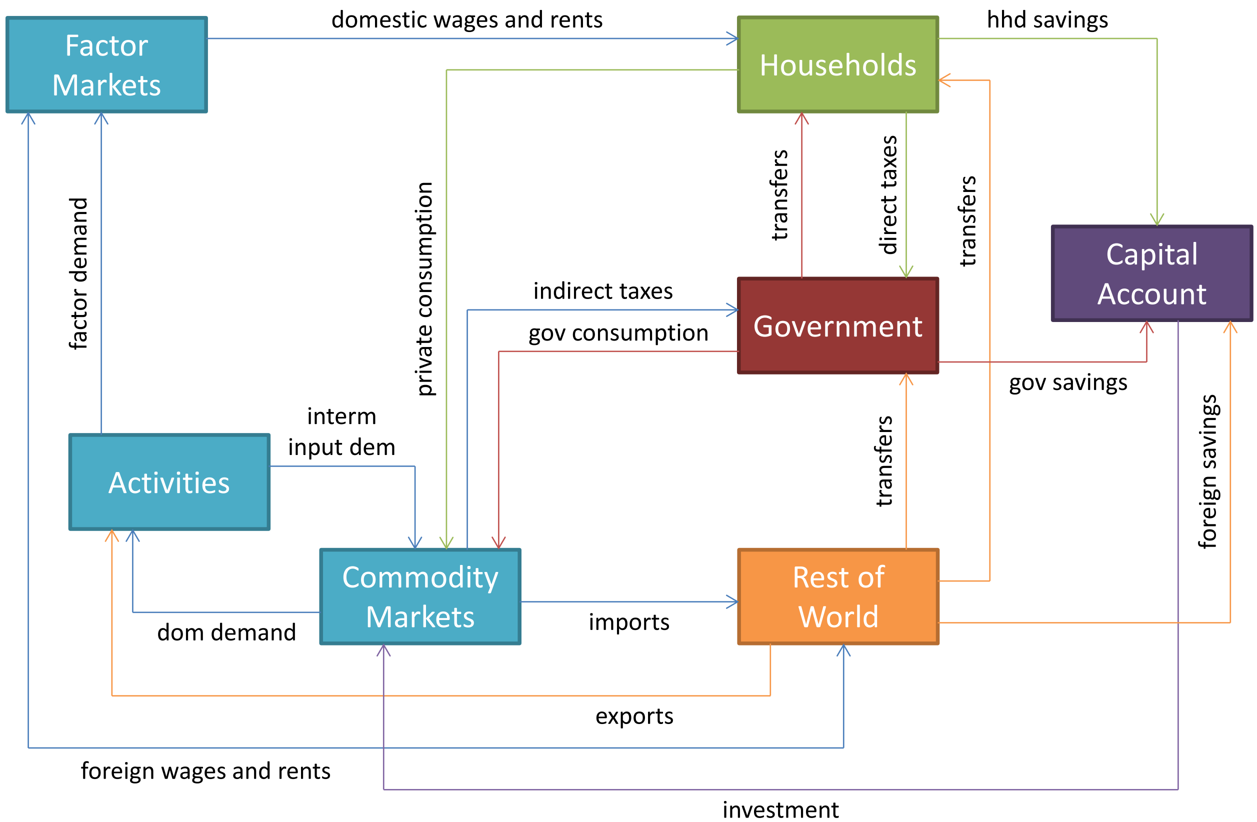
2.1. Computable General Equilibrium Model

The fact that many policies and external shocks induce complex interactions between numerous agents makes it difficult to predict what effects they will have, including who will win and who will lose. CGE modelling offers a systematic method for predicting both the direction and approximate sizes for the impacts of policies and external shocks on different agents. This study employs a single-country recursive dynamic Computable General Equilibrium (CGE) model to evaluate the impact of alternative scenarios on the Haitian economy.[3] The mathematical statement of the model is presented in Appendix A.

The model integrates a relatively standard recursive dynamic computable general equilibrium model with additional equations and variables that single out: (a) the impact of public capital investment in infrastructure on sectoral productivity, (b) the workers migration between rural/informal and urban/formal sectors, (c) the foreign tourism demand, (d) the consequences of government spending in qualified and non-qualified labor, (e) alternative financing options to the central government. Thus, this CGE model offers a combination of policy-relevant features for the study of various policy counterfactual scenarios for Haiti. Figure 2.1 depicts, for each simulation period, the circular flow of income within the economy and between the economy and the rest of the world.

[3] In Banerjee et al. (2015), a similar model was used to assess the impact of a tourism-related investment in the Sud department of Haiti.

Figure 2.1: circular income flow in the Haiti computable general equilibrium; within-period module



Source: Author's own elaboration.

In any single year, the Haiti CGE has the structure summarized in the above figure. Activities produce, selling their output at home or abroad (i.e., the rest of the world), and using their revenues to cover their costs (of intermediate inputs, factor hiring and taxes). Their decisions to pursue particular activities with certain levels of factor use are driven by profit maximization. The shares exported and sold domestically depend on the relative prices of their output in world and domestic markets.

The model identifies four types of institutions: households, government, the rest of the world, and foreign tourists. Households earn incomes from factors and transfers. These are used for consumption, direct taxes, and savings. Their consumption decisions change in response to income and price changes. By construction (and as required by the household budget constraints), the consumption value of the households equals their income net of direct taxes and savings. The government gets its receipts from taxes and transfers from abroad; it uses these for consumption, transfers to households, and investment, drawing on the loanable funds market for supplementary funding. To remain within its budget constraint, it either adjusts some part(s) of its spending on the basis of available receipts or mobilizes additional receipts in order to finance its spending plans. The rest of the world (which appears in the balance of payments) sends foreign currency to Haiti in the form of transfers to its government and households. In turn, Haiti uses these inflows to finance its imports. The balance of payments clears (inflows and outflows are equalized) via adjustments in the real exchange rate (the ratio between the international and domestic price levels), influencing export and import quantities and values in foreign currency. Investment financing is provided from savings by households, government, and the rest of the world. Tourism demand from rest of the world (exports) is modeled as an exogenous volume. In turn, total tourism demand is disaggregated across locally produced commodities using fixed coefficients.

In domestic commodity markets, flexible prices ensure balance between demands for domestic output from domestic demanders and supplies to the domestic market from domestic suppliers. The part of domestic demands that is for imports from the rest of the world faces exogenous prices – Haiti is viewed as small in world markets, without any impact on the import and export prices that it faces. Domestic demanders decide on import and domestic shares in their demands on the basis of the relative prices of commodities from these two sources. Similarly, domestic suppliers (the activities) decide on the shares for exports to the rest of the world and domestic supplies on the basis of the relative prices received in these two markets.

Factor markets reach balance between demands and supplies via wage (or rent) adjustments. Across all factors, the factor demand curves are downward-sloping reflecting the responses of production activities to changes in factor wages. In the case of labor, unemployment is endogenous. For each labor type, the model includes a wage curve that imposes a negative relationship between the real wage and the unemployment rate (Blanchflower and Oswald, 2004). This type of wage equation can be derived from trade union wage models, as well as from efficiency wage models (see, for example, Devarajan et al. (1999) and Cicowiez and Sánchez (2010)). For non-labor factors, the supply curves are vertical in any single year.

Model Dynamics

In our CGE, growth over time is largely endogenous. The economy grows due to accumulation of capital determined by investment and depreciation, labor (determined by exogenously imposed projections), as well as because of improvements in total factor productivity (TFP) which have both endogenous and exogenous components. Apart from an exogenous component, TFP of any production activity potentially depends (usually, positively) on the levels of government capital stocks and economic openness. The accumulation of capital is through investment financed by domestic savings and foreign inflows. Increased capital is allocated across sectors according to their relative profitability. Once installed, capital becomes sector-specific and can only by adjusted through exogenously-determined depreciation and the attraction of new investments.

2.2. Social Accounting Matrix and Other Data

The basic accounting structure and much of the underlying data required to implement our Haiti CGE model is derived from a Social Accounting Matrix (SAM) for Haiti. A SAM is a comprehensive, economy-wide statistical representation of the modeled economy at a specific point in time. It is a square matrix with identical row and column accounts where each cell in the matrix shows a payment from its column account to its row account. It can be used for descriptive purposes and is the key data input for a CGE. Major accounts in Haiti SAM are: activities that carry out production; commodities (goods and services) which are produced and/or imported and sold domestically and/or exported; factors used in production which include labor, capital, land and other natural resources; and institutions such as households, government, and the rest of the world. Generally speaking, most features of the SAM are familiar from social accounting matrices used in other models.[4]

[4] See Pyatt and Round (1985) or King (1981) for a more detailed introduction to SAM construction and interpretation.

As is usually done, we use the SAM to define base-year values for the bulk of the model parameters, including production technologies, sources of commodity supplies (domestic output or imports), demand patterns (for household and government consumption, investment and exports), transfers between different institutions, and tax rates. A stylized (Macro-)SAM for Haiti is provided in Table 2.1. Haiti GDP reached 367,215 million gourdes in FY 2013, based on data from the supply and use table.[5] In FY 2013, the government current account surplus was around 1.4% of GDP and government current consumption was 8.5 of GDP. Regarding international trade, Haiti exported 12.2 percent of GDP and imported 46.7 percent of GDP (Table 2.1). Remittances (transfers) are the single largest source of earnings in the current account balance of Haiti, equivalent to 21.1 percent of GDP in FY 2013.

Table 2.1: Macro-SAM for Haiti FY 2013
(percent of GDP)

	a-agr	a-nagr	c-agr	c-nagr	f-lab	f-cap	tax-ind	tax-imp	tax-dir	marg	h-rur	h-urb	gov	row	sav	inv	invg	total
a-agr			31.0	0.0														31.0
a-nagr			0.6	118.6														119.2
c-agr	9.1	4.7									13.1	15.6		0.9		0.0	0.0	43.3
c-nagr	4.0	34.9								33.1	24.1	49.7	2.2	11.3		26.2	3.7	189.0
f-lab	7.9	43.4																51.2
f-cap	10.0	33.3												0.8				44.2
tax-ind	0.0	3.0	0.0	-0.9														2.1
tax-imp			0.3	3.0														3.3
tax-dir											0.4	2.1						2.6
marg			4.2	28.9														33.1
h-rur					18.9	7.6							2.7	4.9				34.1
h-urb					32.3	36.4							4.8	16.2				89.7
gov							2.1	3.3	2.6		0.0	0.2		2.8				11.1
row			7.2	39.4		0.2					0.5	2.4	0.0					49.8
sav											-4.0	19.6	1.4	12.8				29.8
inv															26.2			26.2
invg															3.7			3.7
total	31.0	119.2	43.3	189.0	51.2	44.2	2.1	3.3	2.6	33.1	34.1	89.7	11.1	49.8	29.8	26.2	3.7	

where a/c-agr = agriculture activities and commodities; a/c-nagr = non-agriculture activities and commodities; f-lab = labor; f-cap = capital; tax-ind = domestic indirect taxes; tax-imp = import

[5] GDP in 2012/2013 was 364,526 million gourdes according to the latest IHSI report on national accounts.

tariffs; tax-dir = direct taxes; marg = trade and transport margins; h-rur and h-urb = rural and urban representative households, respectively; gov = government; row = rest of the world; sav = savings; inv and invg = private and government investment, respectively.

Source: Author's elaboration.

As explained, the Haiti CGE was calibrated to a FY 2013 Social Accounting Matrix (SAM) and other data for Haiti. The main sources of information for the construction of the Haiti FY 2013 SAM were the supply and use tables for the same year, complemented by data on the balance of payments and government finance statistics as well as the ECVMAS 2012. Table 2.2 shows the accounts in the SAM, which determine the size (i.e., disaggregation) of the model. Thus, the SAM/model identifies 22 activities and commodities. The factors of production include two types of labor, each of which is linked to a level of education (unskilled is less than completed secondary, and skilled is completed secondary or above). The growth in the labor force and changes in its composition are exogenous, allowing us to consider alternative counterfactual scenarios. The non-labor factors include public capital stocks (i.e., one for each government sector), a private capital stock, land, and a natural resource used/extracted in mining. The SAM also includes current accounts for institutions (household, government, rest of world, and foreign tourists), investment accounts (one per capital stock), and auxiliary accounts for taxes and trade and transport margins.

Table 2.2: accounts in the Haiti FY 2013 Social Accounting Matrix

Category (#)		Item	Category (#)	Item
Sectors (activities and comm) (22)	**Primary (2)**	Agr, hunting and forestry; Fishing	**Factors (5)**	Labor, unskilled
		Mining and quarrying		Labor, skilled
	Manufact (10)	Food prod and beverages		Capital
		Tobacco prod		Land
		Textiles, wearing apparel and leather		Natural resource, extractive
		Wood and of prod of wood and cork	**Trade and transport margins (3)**	Dist marg, domestic
		Paper and paper prod; Publishing		Dist marg, imports
		Chemicals; Rubber and plastics		Dist marg, exports
		Other non-metallic mineral prod	**Taxes and subsidies (5)**	Taxes on activities
		Basic metals		Taxes on commodities
		Fabricated metal prod; Mach and equip		Subsidies on commodities
		Other manufactures		Tariffs
	Services (10)	Electricity and water supply		Taxes on income
		Construction	**Institutions (13)**	Household, rural, quintiles (5)
		Wholesale and retail trade		Household, urban, quintiles (5)
		Hotels and restaurants		Government
		Transport, storage and comm		Rest of world
		Financial intermediation		Foreign tourists
		Other services	**Investment (8)**	Savings
		Education, government		Investment, private
		Helath, government		Investment, government agriculture infra
		Public administration		Investment, government transport infra
				Investment, government education
				Investment, government health
				Investment, government other
				Stock change

Source: Author's elaboration.

On the basis of SAM data, Table 2.3 summarizes the sectoral structure of Haiti's economy in FY 2013: sectoral shares in value-added, production, employment, exports and imports, as well as the split of domestic sectoral supplies between exports and domestic sales, and domestic sectoral demands between imports and domestic output. For instance, while (primary) agriculture represents a significant share of employment (around 41 percent), its shares of value added, production, and exports are much smaller (in the range of 7.5-20 percent). The share of its output that is exported is around 2.5 percent while 19.6 percent of domestic demands are met via imports. On the other hand, Textiles, wearing apparel and leather products represent a significant share of export revenue (around 48.1%), while their share in total value added is about 2.8% (column VAshr). The Haiti 2012/2013 SAM also reports taxes paid by institutions, commodity sales, value added, activities, exports, and tariffs; total tax revenue reached 9% of GDP in 2012/2013, a relatively low figure when compared to other LDCs (see WDI).

Table 2.3: sectoral structure of Haiti's economy in FY 2013
(percent)

Sector	VAshr	PRDshr	EMPshr	EXPshr	EXP-OUTshr	IMPshr	IMP-DEMshr
Agr, hunting and forestry; Fishing	19.4	21.0	41.0	7.3	2.5	15.5	19.6
Mining and quarrying	0.2	0.2	0.0	0.0	0.0	0.1	12.0
Food prod and beverages	1.9	4.6	0.5	2.0	2.5	14.2	52.0
Tobacco prod	0.0	0.1	0.0	0.0	0.0	0.3	58.2
Textiles, wearing apparel and leather	2.8	4.4	1.2	48.1	81.1	17.0	87.3
Wood and of prod of wood and cork	0.4	0.5	0.1	2.0	12.4	1.5	51.0
Paper and paper prod; Publishing	0.5	0.9	0.1	0.0	0.0	1.3	31.0
Chemicals; Rubber and plastics	0.2	0.5	0.0	1.3	13.0	15.0	92.0
Other non-metallic mineral prod	0.4	0.6	0.1	0.0	0.1	1.2	39.7
Basic metals	0.1	0.2	0.0	0.0	0.0	2.2	76.0
Fabricated metal prod; Mach and equip	0.1	0.1	0.0	1.1	45.0	11.4	98.7
Other manufactures	0.7	1.5	0.2	18.2	66.7	0.7	33.0
Electricity and water supply	1.8	2.7	0.3	0.0	0.0	0.0	0.0
Construction	23.9	19.0	5.9	0.0	0.0	0.0	0.0
Wholesale and retail trade	26.0	22.0	28.6	0.0	0.0	0.0	0.0
Hotels and restaurants	0.3	0.8	0.3	10.2	100.0	1.2	100.0
Transport, storage and comm	14.2	13.9	3.7	8.5	5.0	15.8	27.1
Financial intermediation	2.0	2.0	2.1	1.3	5.0	1.7	21.1
Other services	3.3	3.5	11.0	0.0	0.0	0.9	7.1
Government services	1.6	1.4	4.8	0.0	0.0	0.0	0.0
Total	100.0	100.0	100.0	100.0	7.0	100.0	31.3

where VAshr = value-added share (%); PRDshr = production share (%); EMPshr = share in total employment (%); EXPshr = sector share in total exports (%); EXP-OUTshr = exports as share in sector output (%); IMPshr = sector share in total imports (%); IMP-DEMshr = imports as share of domestic demand (%).

Source: Author's calculations based on FY 2013 Haiti SAM and employment data.

Table 2.4 shows the factor shares in total sectoral value added. For example, the table shows that agriculture is relatively intensive in the use of unskilled labor and labor; this information will be useful to analyze the results from the Haiti CGE simulations. In turn, Government services (i.e., education, health and public administration) and Financial intermediation are relatively intensive in the use of skilled labor.

Table 2.4: sectoral factor intensity, Haiti FY 2013
(percent)

Sector	Labor, unskilled	Labor, skilled	Capital	Nat Res	Total
Agr, hunting and forestry; Fishing	40.3	3.8	9.5	46.4	100.0
Mining and quarrying	14.0	31.6	31.5	23.0	100.0
Food prod and beverages	18.6	41.9	39.6	0.0	100.0
Tobacco prod	21.9	49.4	28.7	0.0	100.0
Textiles, wearing apparel and leather	27.4	61.7	10.9	0.0	100.0
Wood and of prod of wood and cork	17.2	38.8	44.1	0.0	100.0
Paper and paper prod; Publishing	18.3	41.3	40.3	0.0	100.0
Chemicals; Rubber and plastics	13.1	29.6	57.3	0.0	100.0
Other non-metallic mineral prod	11.8	26.7	61.5	0.0	100.0
Basic metals	21.7	48.9	29.4	0.0	100.0
Fabricated metal prod; Mach and equip	13.6	30.8	55.6	0.0	100.0
Other manufactures	15.4	34.8	49.8	0.0	100.0
Electricity and water supply	10.1	22.7	67.2	0.0	100.0
Construction	18.1	19.4	62.5	0.0	100.0
Wholesale and retail trade	44.0	25.3	30.7	0.0	100.0
Hotels and restaurants	40.4	23.2	36.4	0.0	100.0
Transport, storage and comm	21.5	36.4	42.1	0.0	100.0
Financial intermediation	13.2	66.1	20.8	0.0	100.0
Other services	18.6	20.3	61.1	0.0	100.0
Government services	5.3	85.1	9.6	0.0	100.0
Total	29.3	24.9	37.0	8.8	100.0

Source: Author's calculations based on FY 2013 Haiti SAM.

In addition to the SAM, our Haiti CGE model requires (a) base year estimates for capital stocks and sectoral employment levels and unemployment estimates for the different labor types, (b) a set of elasticities (for production, consumption and trade), (c) population projections by household group (i.e., rural and urban), and (d) a baseline projection for growth in GDP at factor cost (see below). In order to estimate sectoral employment we combined population data from UN with estimates for the unemployment rate computed from the ECVMAS (2012). In turn, elasticities were given a value based on the available evidence for comparable countries; given the implied uncertainty, we performed a systematic sensitivity analysis of the results with respect to their value.

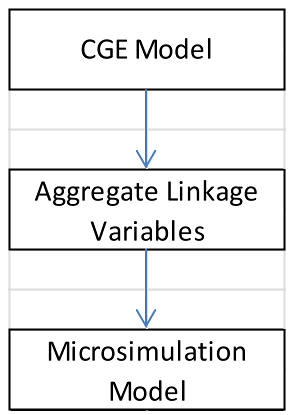
For elasticities, the following values were used: (a) the elasticity of substitution among factors is in the 0.2–1.15 range, relatively low for primary sectors and relatively high for manufactures and services (see Narayanan et al. (2015)); (b) the wage curve has an unemployment-elasticity of -0.1 (see Blanchflower and Oswald (2005)); and (c) based on Sadoulet and de Janvry (1995), trade elasticities are in the 0.5-2 range. Finally, note that for each set of simulations we conducted a systematic sensitivity analysis of our CGE model results with respect to their value.

2.3. Microsimulation Model and Data

Generally speaking, CGE models are an effective tool in capturing aggregate responses to shocks introduced, for example, by an improvement in the terms of trade. On the other hand, the standard configuration of a CGE model is not well suited for analysis of questions related to poverty and income inequality. This is due to the fact that most CGE models use a representative household (RH) formulation where all households in an economy are aggregated into one or a few households (10 in our case) to represent household and consumer behavior. The main limitation of the RH formulation is that intra-household income distribution does not respond to shocks introduced into the model.

To provide greater resolution with regard to household-level impacts, we generate results in terms of poverty and inequality at the micro level by linking the CGE model with a microsimulation model (see Figure 2.2). The two models interact in a sequential “top-down” fashion (i.e., without feedback): the CGE communicates with the microsimulation model by generating a vector of (real) wages[6], aggregate employment variables such as labor demand by sector and the unemployment rate, and non-labor income. The functioning of the labor market thus plays an important role, and the CGE model determines the changes in employment by factor type and sector, and changes in factor and product prices that are then used for the microsimulations.

Figure 2.2: the Macro-Micro approach



Source: Author's elaboration.

To build the microsimulation model, the household survey Enquête sur les Conditions de Vie des Ménages Après Seisme (ECVMAS) for the year 2012, conducted by the Haitian Institute of Statistics and Informatics (IHSI), was used. These data cover 23,555 individuals in 4,930 households in all of Haiti. The ECVMAS is the latest available household survey in Haiti. No attempt was made to reconcile the household survey data with the national accounts. Instead, the results from the CGE model are transmitted to the microsimulation model as percentage deviations from base values.[7] The 2012 poverty rates using the poverty line recently estimated by the World Bank (2014) are calculated as 58.6% poverty and 23.7% extreme poverty at the national level.

[6] The real wage is defined in terms of the CPI; see the CGE model mathematical statement in the Appendix A.

[7] The ECVMAS 2012 was processed as part of the Socio-Economic Database for Latin America and the Caribbean (CEDLAS and The World Bank, 2012); see <http://sedlac.econo.unlp.edu.ar/eng/index.php>.

The microsimulation model follows the non-parametric method described in Vos and Sanchez (2010) but was extended to consider changes in non-labor income.[8] First, the labor market structure is defined in terms of rates of unemployment *U* among different segments of the population at working age (in this case, defined according to skill), the structure of employment *S* (in this case, defined according to sector of activity *S*) and (relative) remuneration *W1*, as well as overall level of remuneration *W2*. The labor-market structure can thus be written as

$$\lambda = (U, S, W1, W2),$$

and the effect of altering each of its four parameters on poverty and inequality can then be analyzed by simulating counterfactual individual earnings and family incomes. Briefly, the model selects at random (with multiple repetitions) from the corresponding labor groups the individuals who will change labor market status (i.e., employment/unemployment and sector) and assigns wages to new workers according to parameters for the average groups. Then, the new wage and employment levels for each individual result in new household per capita incomes that are then used to determine the new poverty and income distribution results. Analytically, we can write

$$yl_i = f(\lambda, X_i)$$

where

yl_i = individual labor income

X_i = individual characteristics; e.g., skill level

In each counterfactual scenario, labor market conditions might change and in turn impact the individual labor income; i.e.,

$$yl_i^* = f(\lambda^*, X_i)$$

where λ^* refers to the simulated labor market structure parameters.

[8] In turn, this approach is an extension of the earnings inequality method developed by Almeida dos Reis and Paes de Barros (1991).

The labor market variables and procedures that link the CGE model with the microsimulations are as follows. This "unemployment effect" is simulated by changing the labor status of the active population in the ECVMAS (2012) sample based on the results from the CGE model. For instance, if according to the CGE simulations unemployment decreases at the same time that employment increases for, say, skilled workers in sector A, the microsimulation model "hires" randomly from the ECVMAS sample among the unemployed skilled. As explained above, individual incomes for the newly employed are assigned based on their characteristics (e.g., educational level) by looking at similar individuals that were originally employed. If the CGE simulations indicate a decrease in employment for a specific labor category and sector, the microsimulation program "fires" the equivalent percentage from the type of labor and sector, and the counterfactual income for those newly unemployed is zero.

The "sectoral structure effect" is simulated by changing the sectoral composition of employment. For those individuals that move from one sector to another, we simulate a counterfactual labor income based on their characteristics and on their new sector of employment, again by looking at individuals that were originally employed in the sector of destination.

To model the change in relative wages, wages for a given labor category (e.g., skilled workers in sector A) are adjusted according to the changes from the CGE simulations but keeping the aggregate average wage for the economy constant. The impact of the change in the aggregate average wage for the economy is simulated by changing all labor incomes in all sectors, by the same proportion, based on the changes from the CGE simulations. Next, all the previous steps are repeated several times and averaged.

For non-labor incomes, government transfers and remittances from abroad are proportionally scaled up or down using changes taken from the CGE model. The final step in the microsimulation model is to adjust the micro data such that the percentage change in the household per capita income matches the change in household per capita income – for each representative household in the CGE simulations. Thus, this residual effect implicitly accounts for changes in all items not previously considered (i.e., non-labor and non-transfer incomes) such as natural resource and capital rents.

Finally, we should note that our Haiti CGE model can only solve for the relative prices and the real variables of the economy. Thus, in order to anchor the absolute price level, a normalization rule has been applied. Specifically, the consumer price index (CPI) is chosen as the numéraire, so all changes in nominal prices and incomes in simulations are relative to the weighted unit price of households' initial consumption bundle (i.e., a fixed CPI). The model is also homogenous of degree zero in prices. In macro terminology, the model displays neutrality of money.

3. Simulations

In this section, we present a short description of the sets of simulations that are analyzed is separate documents. In separate documents, we provide detail definitions of the different scenarios and analyze the results for both the CGE model and the microsimulation model.

- Government and Institutional Capacity
- Production and Productive Sectors
- Human Development
- Macroeconomic Shocks

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Appendix A: Haiti CGE Model Mathematical Statement

In order to simplify the model presentation, in what follows assumptions are made in order to simplify the mathematical statement of the model. For example, we assume that all tax rates are exogenous, one trade partner, no enterprises as separate institutions, no value added tax, no tax on factor use, no consumption subsidies, among others. Of course, all this elements are available in the GAMS (General Algebraic Modeling System) model code. In addition, the model presentation assumes the macroeconomic closure rule used for model simulations in Section 3.

In the mathematical statement of the model we use the following sets:

ac = all accounts in the social accounting matrix and other elements

a(ac) = activities

c(ac) = commodities

f(ac) = factors

i(ac) = institutions (i.e., households, enterprises, government, rest of the world)

h(i) = households

gov(i) = government

row(i) = rest of the world

inv = investment accounts

invg = government investment accounts

invng = government investment accounts (i.e., private/public enterprises)

where the notation i(j) implies that j is a subset of i. Besides, the following notation is used:

- endogenous variables = upper-case Latin letters;
- exogenous variables = upper-case Latin letters with a bar on top – usually as part of the model "closure rule" (see below);
- parameters = lower-case Latin letters or lower case Greek letters; and
- set indices = lower-case Latin letters as subscripts to variables and parameters.

In addition, variable names for quantities and prices start with Q and P, respectively. In what follows we omit the time set, except when reference is made to non-current periods. Thus, unless stated otherwise, all endogenous and exogenous variables have implicit the time set t.

Variables and Parameters

Endogenous Variables

$AWF_{f,t}$ = average remuneration of factor f

$CALTFP_t$ = TFP in calibration run

CAB_t = current account balance

$CON_{h,t}$ = household consumption expenditure

CPI_t = consumer price index

DPI_t = index for domestic producer prices (PDS-based)

EG_t = total current government expenditure

EXR_t = exchange rate (dom. currency per unit of for. currency)

$FD_{f,a,t}$ = quantity demanded of factor f from activity a

$FPRD_{f,a,t}$ = productivity term for factor f in act a

$FS_{f,t}$ = supply of factor f

$GDAJ_t$ = government demand scaling factor

$GFCF_t^{GOV}$ = government gross fixed capital formation

$GFCF_t^{NGOV}$ = non-government gross fixed capital formation

$IADJ_{invg,t}^{GOV}$ = government investment scaling factor

$IADJ_t^{NGOV}$ = non-government investment scaling factor

$IND_{a,t}$ = non-gov investment by destination

$INDG_{invg,t}$ = gov investment by destination

IT_t^{GOV} = gov total investment

IT_t^{NGOV} = non-gov total investment

$KG_{invg,t}$ = government capital stock

$MPS_{h,t}$ = marginal propensity to save for domestic non-gov inst insdng

$MPSADJ_t$ = savings rate scaling factor

$PA_{a,t}$ = output price of activity a

$PDD_{c,t}$ = demand price for commodity c produced and sold domestically

$PDS_{c,t}$ = supply price for commodity c produced and sold domestically

$PE_{c,t}$ = export price for c

$PINTA_{a,t}$ = price of intermediate aggregate

$PK_{invg,t}^{GOV}$ = replacement cost of gov capital

$PK_{invng,t}^{NGOV}$ = replacement cost of non-gov capital

$PM_{c,t}$ = import price for c

$PQD_{c,ac,t}$ = composite commodity demand price for c demanded by ac

$PQS_{c,t}$ = composite commodity supply price for c

$PVA_{a,t}$ = value-added price for activity a

$PX_{c,t}$ = producer price for commodity c

$QA_{a,t}$ = level of activity a

$QD_{c,t}$ = quantity sold domestically of domestic output c

$QE_{c,t}$ = quantity of exports for commodity c

$QG_{c,t}$ = quantity of government demand for commodity c

$QH_{c,h,t}$ = quantity consumed of commodity c by household h

$QINT_{c,a,t}$ = quantity of commodity c as intermediate input to activity a

$QINTA_{a,t}$ = quantity of aggregate intermediate input

$QINV_{c,t}$ = quantity of investment demand for commodity c

$QM_{c,t}$ = quantity of imports of commodity c

$QQ_{c,t}$ = quantity of goods supplied domestically (composite supply)

$QT_{c,t}$ = quantity of trade and transport demand for commodity c

$QVA_{a,t}$ = quantity of aggregate value added

QX_c = quantity of domestic output of commodity c

$REXR_t$ = real exchange rate

$RGFCF^{GOV}$ = real gross fixed capital formation gov

$RGFCF_{invng}^{NGOV}$ = real gross fixed capital formation non-gov

SG_t = government savings

SH_h = savings of household h

$SROW_t$ = foreign savings (foreign currency)

TFP_a = sectoral TFP index

$TR_{ac,ins,t}$ = transfers from ins to ac

$TRADJ_{ac,t}$ = scaling factor for transfers

$UERAT_{f,t}$ = unemployment rate for factor f

$WALRAS_t$ = dummy variable (zero at equilibrium)

$WF_{f,t}$ = average price of factor f

$WFDIST_{f,a,t}$ = wage distortion factor for factor f in activity a

$YF_{f,t}$ = factor income

YG_t = government income

$YH_{h,t}$ = income household h

$YIF_{i,f,t}$ = income of institution ins from factor f

Exogenous Variables and Parameters

iva_a = aggregate value added coefficient

$inta_a$ = aggregate intermediate input coefficient

$\delta_{f,a}^{VA}$ = share parameter for CES activity VA production function

ϕ_a^{VA} = shift parameter for CES activity VA production function

σ_a^{VA} = elasticity of substitution between factors

ρ_a^{VA} = exponent in the value added production function for a

$ica_{c,a}$ = intermediate input c per unit of aggregate intermediate

$\theta_{a,c}$ = yield of output c per unit of activity a

pwe_c = export price for c (foreign currency)

pwm_c = import price for c (foreign currency)

$icd_{c',c}$ = trade and transport input of c per unit of commodity c' produced and sold domestically

$ice_{c',c}$ = trade and transport input of c per unit of commodity c' exported

$icm_{c',c}$ = trade and transport input of c per unit of commodity c' imported

$sh^F_{i,f}$ = share for institution i in the income of factor f

$\overline{mps}_h$ = marginal propensity to save household h

$sh^{TR}_{i,i'}$ = share of institution i in post-tax post-savings income of institution i'; $i' \in \{h,e\}$

$ta_{a,t}$ = rate of tax on producer gross output value

$te_{c,t}$ = export tax rate for commodity c

$tf_{f,t}$ = rate of direct tax on factor income

$tm_{c,t}$ = import tariff rate for commodity c

$tq_{c,t}$ = rate of sales tax

$ty_{i,t}$ = rate of income tax for household h

$\overline{tr}_{ac,i}$ = exogenous component of transfers from ins i to ac; $i \in \{gov, row\}$

δ^M_c = Armington function share parameter for imports commodity c

δ^{DD}_c = Armington function share parameter for domestic commodity c

ϕ^Q_c = Armington function shift parameter for commodity c

σ^Q_c = elasticity of substitution between domestic goods and imports for c

$\rho^Q_c = \left(1-\sigma^Q_c\right)/\sigma^Q_c$

δ^E_c = CET function share parameter for exports commodity c

δ_c^{DS} = CET function share parameter for domestic commodity c

ϕ_c^X = CET function shift parameter for commodity c

σ_c^X = elasticity of transformation between domestic sales and exports for c

$\rho_c^X = \left(1+\sigma_c^X\right)/\sigma_c^X$

$\overline{qg}_c$ = quantity of government demand for commodity c

$qhmin_{c,h}$ = subsist cons of commodity c for household h

$\delta_{c,h}^{LES}$ = marginal share of household consumption on commodity c

cc_i^{NGOV} = quantity of commodity c per unit of non-gov investment in invng

cc_i^{GOV} = quantity of commodity c per unit of gov investment in invg

$phillips_f$ = elasticity of real wage with respect to unemployment rate

$qdstk_c^{NGOV}$ = changes in inventories non-government

$qdstk_c^{GOV}$ = changes in inventories government

$cwts_c$ = weight of commodity c in the CPI

$dwts_c$ = domestic sales price weights

δ^{GOV} = depreciation rate public capital

δ^{NGOV} = depreciation rate private capital

$\overline{qinvg}_{invg,t}$ = government investment in sector invg

$\overline{qinvng}_{invng,t}$ = non-government investment in sector invng

Equations

The model equations are organized in the following eight groups: production, incomes and savings, prices, international trade, final consumption, equilibrium conditions, miscellaneous, and investment by destination (i.e., dynamics).

Production

In the first place, we describe the production function, which is organized in two levels (see Figure A.1). As shown in the figure, we use nested Leontief (i.e., fixed coefficients) and CES (Constant Elasticity of Substitution) production functions. Equations (PF1) and (PF2) show that value added (QVA_a) and the aggregate of intermediate inputs ($QINTA_a$) are a fixed proportion of the activity production level (QA_a), respectively.

$$QVA_a = iva_a QA_a \qquad \text{(PF1)}$$

$$QINTA_a = inta_a QA_a \qquad \text{(PF2)}$$

Equations (PF3) and (PF4) represent the first order conditions of the optimization problem solved by the representative firm in each industry or activity (i.e., cost minimization/profit maximization). The value added production technology is a CES function. The remuneration to factor *f* paid by the activity *a* is computed as $WF_f WFDIST_{f,a}$, where $WFDIST_{f,a}$ is a "distortion" factor that allows modeling cases in which the factor remuneration differs across activities.[9] As we will see, this method to compute the remuneration of factor f in each activity allows to easily selecting among alternative closures (i.e., mechanisms to equalize supply and demand) in the factor markets.[10]

$$QVA_a = \phi_a^{VA} TFP_a \left(\sum_f \delta_{f,a}^{VA} QF_{f,a}^{-\rho_a^{VA}} \right)^{-\frac{1}{\rho_a^{VA}}} \qquad \text{(PF3)}$$

---

[9] In this presentation we assume that its value is exogenous for labor and exogenous for capital; its value can be computed by combining the social accounting matrix with employment data by activity.

[10] Besides, for the factors considered as specific, equation (PF4) is interpreted as an equilibrium condition between factor supply and demand.

$$FD_{f,a} = \left(\frac{PVA_a}{WF_f WFDIST_{f,a}} \right)^{\sigma_a^{VA}} \left(\delta_{f,a}^{VA}\right)^{\sigma_a^{VA}} \left(\phi_a^{VA} TFP_a\right)^{\sigma_a^{VA}-1} QVA_a \quad \text{(PF4)}$$

Individual intermediate inputs are also a fixed share of output. However, note that in equation (PF5) intermediate inputs are a fixed share of the aggregate intermediate input which, in turn, is a fixed proportion of output (equation (PF2)).[11]

$$QINT_{c,a} = ica_{c,a} QINTA_a \quad \text{(PF5)}$$

Equation (PF6) computes the production of each product on the basis of the $\theta_{a,c}$ parameter, which represents the production of product *c* per unit produced of activity *a*. Thus, following the supply and use tables, our model differentiates between activities and commodities/products. In addition, an activity can produce more than commodity and the same commodity may be produced by more than one activity.

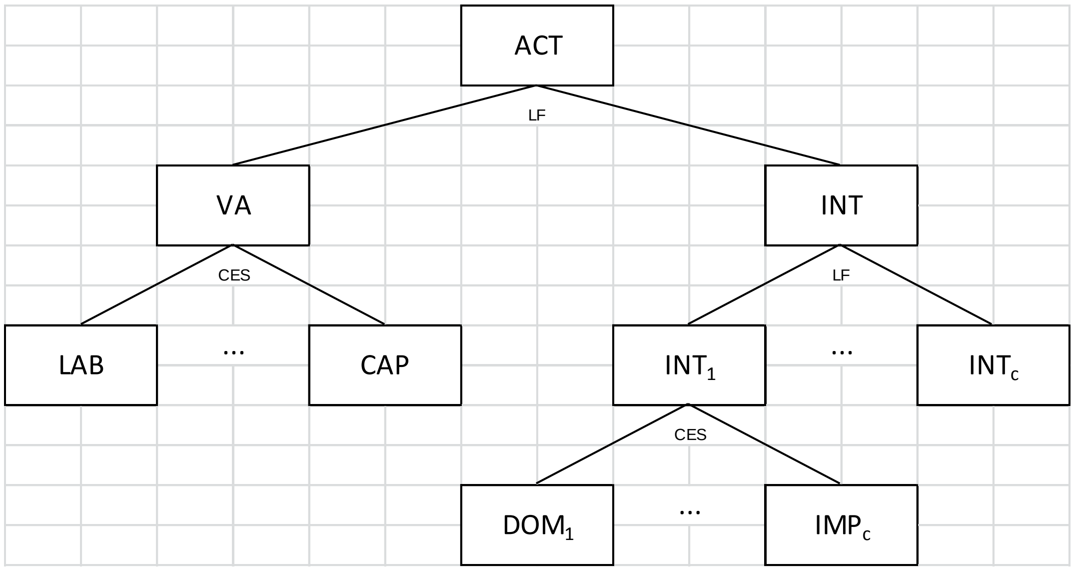
$$QX_c = \sum_a \theta_{a,c} QA_a \quad \text{(PF6)}$$

Equation (FP7) computes sectoral total factor productivity (TFP) as a function of (a) an exogenous component, and (b) the size of the public infrastructure capital stocks. Thus, an increase in the provision of public infrastructure of type *invginf* (e.g., roads) would have positive impacts on sectoral TFP, more or less strong depending on the value assigned to the $tfpelas_{a,invg}$ elasticity parameter. In equation (FP7), variable KG_{invg}^{00} refers to the public capital stock in sector *invg* in the base year. In other words, our model assumes that, based on available empirical evidence, that public infrastructure has positive externalities on sectoral TFP. For model calibration, the initial public capital stock can be estimated through alternative methods; for example, based on recent data for public investments.

$$TFP_{a,t} = tfpexog_{a,t} CALTFP_t \prod_{invg \in invginf} \left(\frac{KG_{invg,t}}{KG_{invg}^{00}} \right)^{tfpelas_{a,invg}} \quad \text{(PF7)}$$

[11] Note that, unlike the $ica_{c,a}$ parameters, the Leontief technical coefficients are expressed as share of output.

Figure A.1: production function



where ACT=activities, VA=value added, INTA=aggregate of intermediate inputs, LAB=labor, CAP=capital, INT=intermediate consumption, DOM=domestic, and IMP=imported.

Source: Author's own elaboration.

Prices

Equation (PR1) implicitly defines the price of value added, as all other variables in that equation are determined elsewhere in the model. For each activity, the price of its intermediate input composite ($QINTA_a$) is a weighted average of the prices of each of the commodities that is demanded as an intermediate input (equation (PR2)), with $ica_{c,a}$ as weights. As we have seen, $ica_{c,a}$ is the quantity of commodity *c* used as an intermediate input in activity *a* per unit of $QINTA_a$. The price of each activity is a weighted average of the prices of the commodities it produces (equation (PR3)).

$$PVA_a QVA_a = PA_a (1 - ta_a) QA_a - PINTA_a QINTA_a \quad \text{(PR1)}$$

$$PINTA_a = \sum_{c \in energ} PQD_{c,a} ica_{c,a} \quad \text{(PR2)}$$

$$PA_a = \sum_c \theta_{a,c} PX_c \quad \text{(PR3)}$$

Equations (PR4) and (PR5) define domestic prices of exports (PE_c) and imports (PM_c), respectively. It is assumed that the modeled economy is small; thus, world prices for exports and imports are given (pwe_c and pwm_c ; also, see below). The government can collect tariffs on imports and taxes on exports, at rates tm_c and te_c , respectively. Besides, the model also considers trade and transport margins applied to exports and imports; i.e., $ice_{c',c}$ and $icm_{c',c}$ represent the quantity of trade/transport commodity *ct* per unit of exports and imports of commodity *c*, respectively.

$$PE_c = (1 - te_c) EXR.pwe_c - \sum_{c' \in ct} PQD_{c',tace} ice_{c',c} \quad \text{(PR4)}$$

$$PM_c = (1 + tm_c) EXR.pwm_c + \sum_{c' \in ct} PQD_{c',tacm} icm_{c',c} \quad \text{(PR5)}$$

Equation (PR6) computes the demand price of the domestic product, by adding to its supply price the corresponding trade and transport margin. Thus, parameter $icd_{c',c}$ refers to the quantity of commodity *c'* (i.e., trade and transport; distribution services) that is required to move one unit of domestic product *c* from the producer to the consumer.

$$PDD_c = PDS_c + \sum_{c' \in ct} PQD_{c',tacd} icd_{c',c} \quad \text{(PR6)}$$

Incomes and Savings

Factors. Equation (YF1) computes the total income of factor *f*. The first term on the right hand side corresponds to total factor payments from activities. Besides, factor *f* can receive transfers from the rest of the world. In turn, equation (YF2) computes the income received by each institution for being the owner of factor *f*, net of the applicable (direct) tax on factor income.

$$YF_f = \sum_a WF_f WFDIST_{f,a} FD_{f,a} + TR_{f,row} \quad \text{(YF1)}$$

$$YIF_{i,f} = sh^F_{i,f} YF_f (1 - tf_f) \quad \text{(YF2)}$$

Households. The income of (representative) household h is the sum of two elements: (1) factor income, and (2) transfers from other institutions (see equation (H1)). Equation (H2) computes the marginal propensity to save for the households. Initially, variable $MPSADJ$ is equal to one.[12] Equation (H3) computes the value of savings for each household in the model, as a linear function of disposable income. Equation (H4) computes the consumption spending by households as their income net of transfers to other institutions, savings, and direct taxes.

$$YH_h = \sum_f YIF_f + \sum_i TR_{h,i} \tag{H1}$$

$$MPS_h = \overline{mps}_h \overline{MPSADJ} \tag{H2}$$

$$SH_h = \alpha_h^{SAV} CPI + MPS_h YH_h (1 - ty_h) \tag{H3}$$

$$CON_h = YH_h (1 - ty_h) - SH_h - \sum_i TR_{i,h} \tag{H4}$$

Government. Equation (G1) computes government income as the sum of three elements: (1) tax collection, (2) transfers from other institutions, and (3) factor income. Note that transfers from the rest of the world are multiplied by the exchange rate so that they are expressed in local currency. The government uses its income to provide goods and services and make transfers to other institutions (equation (G2)). Equation (G3) computes government savings as the difference between current income (YG) and current spending (EG).

[12] Besides, in this presentation it is assumed that $MPSADJ$ is an exogenous variable.

$$
\begin{aligned}
YG = & \sum_{i \in insdng} ty_i YH_i \\
& + \sum_c tq_c \left(PDD_c QD_c + PM_c QM_c \right) \\
& + \sum_c tm_c EXR.pwm_c QM_c \\
& + \sum_c te_c EXR.pwe_c QE_c \\
& + \sum_a ta_a PA_a QA_a \\
& + \sum_f tf_f YF_f \\
& + \sum_i TR_{gov,i} \\
& + \sum_f YIF_{gov,f}
\end{aligned}
\tag{G1}
$$

$$
EG = \sum_c PQ_c QG_c + \sum_i TR_{i,gov} \tag{G2}
$$

$$
SG = YG - EG \tag{G3}
$$

Rest of the World. The rest of the world is represented through the current account of the balance of payments, expressed in foreign currency (equation (RW1)). The left (right) hand side shows the inflows (outflows) of foreign exchange. The current account balance of the balance of payments is the negative of foreign savings (equation (RW2)).

$$
\begin{aligned}
& \sum_c pwe_c QE_c + \frac{\sum_{ac} TR_{ac,row}}{EXR} + \overline{SROW} = \\
& \sum_c pwm_c QM_c + \frac{\sum_i TR_{row,i}}{EXR} + \sum_f \frac{YIF_{row,f}}{EXR}
\end{aligned}
\tag{RW1}
$$

$$
CAB = -\overline{SROW} \tag{RW2}
$$

Transfers. The model provides a detailed treatment for transfers. Specifically, transfers from domestic non-government institution *i* (e.g., households, enterprises, others) to institution *i*' are modeled as an exogenous share of the income of institution *i* net of savings and direct taxes (equation (TR1)).[13] In turn, government transfers to domestic institutions are indexed to consumer price index (equation (TR2)), so that their value is constant in real terms. On the other hand, transfers from government to the rest of the world and from the rest to domestic institutions are indexed to the nominal exchange rate – see equations (TR3) and (TR4), respectively. Thus, their value in foreign currency is kept constant.[14] Equation (TR5) refers to the factor income from abroad, also expressed in foreign currency.

$$TR_{i,h} = sh^{TR}_{i,h}\left(YH_h(1-ty_h)-SH_h\right) \quad \text{(TR1)}$$

$$TR_{insdng,gov} = \overline{tr}_{insdng,gov}CPI \quad \text{(TR2)}$$

$$TR_{row,gov} = \overline{tr}_{row,gov}EXR \quad \text{(TR3)}$$

$$TR_{insd,row} = \overline{tr}_{insd,row}EXR \quad \text{(TR4)}$$

$$TR_{f,row} = \overline{tr}_{f,row}EXR \quad \text{(TR5)}$$

International Trade

Imports. On the consumption side, and following the Armington (1969) assumption, we assume that products are differentiated based on their country of origin (i.e., Haitian textiles are different from Italian textiles). Consequently, it is possible to consider two-way trade (i.e., the same product is exported and imported simultaneously). To model the imperfect substitution between domestic and imported products, we use a CES function (equation (IM1)).[15] Equation (IM2) is the tangency condition that determines the domestic/imported mix of total supply/demand for each product. Equation (IM3) computes the supply price of the composite product QQ_c as a weighted average of the domestic and imported varieties of commodity c. Equation (IM4) computes the demand price of the composite product QQ_c. The sales tax is

[13] In case enterprises are present in the SAM as an institution, it is assumed that they can save and pay direct taxes, but do not demand commodities. In practice, enterprises usually receive most of the capital income to distribute it among the other institutions, such as households and the rest of the world.

[14] In equations (TR3)-(TR5) the trbar parameter is expressed in foreign currency units.

[15] The elasticity of substitution between domestic purchases and imports is $\sigma^Q_c = 1/\left(1+\rho^Q_c\right)$.

imposed on the composite product. For products that are only bought domestically or that are only imported, equation (IM1) is replaced with equation (IM1’) at the same time that equation (IM2) is excluded from the model.

$$QQ_c = \phi_c^Q \left(\delta_c^M QM_c^{-\rho_c^Q} + \delta_c^{DD} QD_c^{-\rho_c^Q} \right)^{-\frac{1}{\rho_c^Q}} \qquad \text{(IM1)}$$

$$QQ_c = QM_c + QD_c \qquad \text{(IM1')}$$

$$\frac{QM_c}{QD_c} = \left(\frac{PDD_c}{PM_c} \frac{\delta_c^M}{\delta_c^{DD}} \right)^{\frac{1}{1+\rho_c^Q}} \qquad \text{(IM2)}$$

$$PQS_c QQ_c = PDD_c QD_c + PM_c QM_c \qquad \text{(IM3)}$$

$$PQD_{c,ac} = PQS_c \left(1 + tq_c\right) \qquad \text{(IM4)}$$

Exports. On the production side, production can be sold in the domestic market and/or exported to the rest of the world. In terms of modeling, we use a CET (Constant Elasticity of Transformation) function (equation (EX1)).[16] Equation (EX2) corresponds to the first order conditions of the profit maximization problem solved by the producer. Equation (EX3) is the zero profit condition for the production of commodity *c*, from where price PX_c is obtained. For products that are only sold domestically or are only exported, equation (EX1) is replaced by equation (EX1’) and equation (EX2) is excluded from the model.

$$QX_c = \phi_c^X \left(\delta_c^E QE_c^{\rho_c^X} + \delta_c^{DS} QD_c^{\rho_c^X} \right)^{\frac{1}{\rho_c^X}} \qquad \text{(EX1)}$$

$$QX_c = QE_c + QD_c \qquad \text{(EX1')}$$

$$\frac{QE_c}{QD_c} = \left(\frac{PE_c}{PDS_c} \frac{\delta_c^{DS}}{\delta_c^E} \right)^{\frac{1}{\rho_c^X - 1}} \qquad \text{(EX2)}$$

$$PX_c QX_c = PDS_c QD_c + PE_c QE_c \qquad \text{(EX3)}$$

[16] The elasticity of transformation between domestic sales and exports is $\sigma_c^X = 1/\left(\rho_c^X - 1\right)$.

Final Consumption

Household consumption expenditure is distributed across commodities according to a Stone-Geary utility function, from which a linear expenditure system is derived (equation (FC1)). Equation (FC2) computes the investment demand of commodity *c*. It is assumed that the commodity composition of investment is exogenous – see parameters $cc_{invng,c}^{NGOV}$ and $cc_{invng,c}^{NGOV}$. Thus, if there is an increase in investment, investment demand for all goods and services will increase in the same proportion.[17] Initially, variable $IADJ$ is equal to one. Equation (FC3) computes the government consumption/provision of commodity *c*. It is assumed that the commodity composition of government consumption is also fixed at its initial values. Initially, variable $GADJ$ is equal to one. Equation (FC4) is the total demand for commodities that provide trade and transport margins; the demand for such commodities is linked to domestic products, imports and exports.

$$QH_{c,h} = qhmin_{c,h} + \frac{\delta_{c,h}^{LES}}{PQD_{c,h}}\left(CON_h - \sum_{c'} PQD_{c',h}\, qhmin_{c',h}\right) \qquad \text{(FC1)}$$

$$QINV_c = \sum_{invng} cc_{invng,c}^{NGOV} RGFCF_{invng}^{NGOV} + \sum_{invg} cc_{invg,c}^{GOV} RGFCF_{invg}^{GOV} \qquad \text{(FC2)}$$

$$QG_c = \overline{qg}_c\, \overline{GADJ} \qquad \text{(FC3)}$$

$$QT_c = \sum_{c'}\left(icm_{c,c'} QM_{c'} + ice_{c,c'} QE_{c'} + icd_{c,c'} QD_{c'}\right) \qquad \text{(FC4)}$$

Unemployment

Equation (U1) is the wage curve for factor f (see Blanchflower and Oswald (1994)). It is assumed that there is a negative relation between the real wage and the unemployment rate, as the value of the phillips parameter is negative. In fact, Blanchflower and Oswald (2005) report a value for the unemployment-elasticity of wage close to -0.1 for a large number of countries. Note that the wage curve is consistent with several stories to explain the presence of

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[17] This presentation assumes that investment is considered as an endogenous variable; see below the discussion of macroeconomic closure rule.

unemployment for the labor market, such as efficiency wages, unions with bargaining power, among others.

$$\frac{WF_f}{CPI} = \frac{WF_f^{00}}{CPI^{00}} \left(\frac{UERAT_f}{UERAT_f^{00}} \right)^{phillips_f} \tag{U1}$$

Equilibrium Conditions

Equation (EQ1) is the equilibrium condition in the market for factor f. As will be shown, this model presentation assumes that all factor supplies are exogenous. However, the supply of each factor (FS_f) can be exogenous or endogenous depending on the selected closure rule.

Equation (EQ2) is the equilibrium condition between supply and demand for each commodity. Total supply, composed of domestic and imported varieties, is used for household consumption, intermediate consumption, investment, government consumption and changes in inventories. Equation (EQ3) is the savings-investment balance; three are the institutions that contribute to total savings: domestic non-government institutions (i.e., households and enterprises), government, and the rest of the world. The variable $WALRAS$ must be zero in equilibrium.

$$FS_f (1 - UERAT_f) = \sum_a FD_{f,a} \tag{EQ1}$$

$$\sum_h QH_{c,h} + \sum_a QINT_{c,a} + QINV_c + QG_c + qdstk_c^{NGOV} + qdstk_c^{GOV} + QT_c = QQ_c \tag{EQ2}$$

$$IT^{NGOV} + IT^{GOV} + WALRAS = \sum_h SH_h + SG + EXR.SROW \tag{EQ3}$$

Miscellaneous

Equation (MIS1) defines the consumer price index as a weighted average of the composite commodity prices for households ($PQD_{c,h}$); the weights are the shares of each commodity in private (i.e., household) consumption. In this presentation CPI is the model numeraire (see below). Equation (MIS2) defines the producer domestic price index as a weighted average of the prices of domestic output sold in the domestic market. Equation (MIS3) defines the real exchange rate, as the ratio between the nominal exchange rate and the producer domestic price index.

$$\sum_{c,h} PQD_{c,h} cwts_{c,h} = CPI \quad \text{(MIS1)}$$

$$\sum_{c} PDS_{c} dwts_{c} = DPI \quad \text{(MIS2)}$$

$$REXR = \frac{EXR}{DPI} \quad \text{(MIS3)}$$

Investment by Destination – Dynamics

Lastly, this group of equations presents the model dynamics. Specifically, the mechanisms used to assign each period private and public investment among sectors are presented. As will be shown, a distinction is made between private and public capital stocks; this is particularly relevant given our interest in simulating increases in the government investment of public infrastructure.

Non-Government Sector. In this case, investment in each period increases the capital stock available in the next period. Then, we need to determine how the new capital is distributed among industries. In our model, for private investment (i.e., households and/or enterprises) we assume that the new capital is distributed across activities based on sectoral differences in capital rates of return. Thus, sectors with a relatively higher (lower) capital rate of return receive a relatively larger (smaller) share of the new capital.

Equation (DP1) computes the price of one unit of private capital; the new capital is assembled using a fixed coefficient production function. Equation (DP2) defines total private investment as the sum of private gross fixed capital formation and the value of change in stocks. Equation (DP3) computes the real gross fixed capital formation, which refers to the quantity of new units of the capital good that will be available to produce the next period. Equation (DP4) can be used to impose an exogenous path for private investment in one or more sectors included in the set *invng* (see above). Equation (DP5) computes the average capital rate of return, as the ratio between total capital income and total capital stock. Equation (DP6) computes the share of each activity in the new capital stock, following the explanation on the previous paragraph. The κ parameter, which varies between zero and one, measures the degree of capital mobility among productive sectors. When κ is zero, investment is distributed among sectors only based on the initial share of each sector in the total capital stock. When κ is positive, investment is distributed among sectors also based on the relative capital returns. Finally, equation (DP8) shows how sectoral capital stocks are updated.

$$PK_{invng}^{NGOV} = \sum_{c} cc_{invng,c}^{NGOV} PQD_{c,invng} \tag{DP1}$$

$$IT^{NGOV} = GFCF^{NGOV} + \sum_{c} PQD_{c,dstk} qdstk_{c}^{NGOV} \tag{DP2}$$

$$GFCF^{NGOV} = \sum_{invng} RGFCF_{invng}^{NGOV} PK_{invng}^{NGOV} \tag{DP3}$$

$$RGFCF_{invng}^{NGOV} = \overline{qinvng}_{invng} \left(1 + IADJ^{NGOV}\right) \tag{DP4}$$

$$AWF_{f} = \frac{\sum_{a} FD_{f,a} WF_{f} WFDIST_{f,a}}{\sum_{a} FD_{f,a}} \tag{DP5}$$

$$IND_{fcap,a} = \sum_{invng \in mfcapinv} RGFCF_{invng}^{NGOV} \frac{FD_{fcap,a}}{\sum_{a'} FD_{fcap,a'}} \left[1 + \kappa \left(\frac{WF_{fcap} WFDIST_{fcap,a}}{AWF_{fcap}} - 1 \right) \right] \tag{DP6}$$

$$FD_{fcap,a} = \left(1 - \delta^{NGOV}\right) FD_{fcap,t-1} + IND_{fcap,a,t-1} \tag{DP7}$$

Government Sector. For the government, investment can be determined in two alternatives ways: (1) as a policy variable (i.e., exogenously), or (2) as a residual to balance the government budget. Equations (DG1), (DG2), (DG3) and (DG4) are similar to equations (DP1), (DP2), (DP3) and (DP4), respectively. Finally, equation (DG6) updates the public capital stocks of period t using public investment from period t-1. For example, an increase in public investment in infrastructure would be modeled as an increase in the value of the relevant element of the $\overline{qinvg}_{invg}$ parameter. Then, an increase in KG_{invg} would be obtained that, in turn, would positively impact on the sectoral TFP (see equation (PF7) above). As mentioned, the model allows identifying more than one type of public capital; for example, different infrastructure sectors such as roads, communications, energy, among others.

$$PK_{invg}^{GOV} = \sum_{c} cc_{invg,c}^{GOV} PQD_{c,invg} \tag{DG1}$$

$$IT^{GOV} = GFCF^{GOV} + \sum_{c} PQD_{c,dstkg} qdstk_{c}^{GOV} \tag{DG2}$$

$$GFCF^{GOV} = \sum_{invg} PK_{invg}^{GOV} RGFCF_{invg}^{GOV} \tag{DG3}$$

$$RGFCF_{invg}^{GOV} = \overline{qinvg}_{invg} \left(1 + IADJ_{invg}^{GOV}\right) \tag{DG4}$$

$$INDG_{invg} = RGFCF_{invg}^{GOV} \tag{DG5}$$

$$KG_{invg,t} = \left(1 - \delta^{GOV}\right) KG_{invg,t-1} + INDG_{invg,t-1} \tag{DG6}$$

In addition, model dynamics require the imposition of growth rate for the other factor endowments, the minimum consumption of households, and transfers model through the $\overline{tr}_{ac,i}$ parameter.