# Appendix A

# LPSM Mathematical Statement

This section presents a mathematical statement of LPSM, showing the relationships that, together with the database, determine the results of model simulations. A good understanding of the structure of the model and its database is required to interpret the simulation results. Given that this model is dynamic, a time index is part of the domains of all variables and the parameters that are most likely to change over time. All model components are potentially active, but whether they are used in any given application depends on the database disaggregation. The equations are split into four blocks: a) production and factors, b) domestic and aggregate foreign trade, c) current accounts of domestic institutions, and d) investment, system constraints, and numéraire. Each section covers one block, and its equations are listed in a table. In model simulations, it is possible to choose among alternative assumptions for (i) payments linking the government, domestic non-government institutions, and the rest of the world; (ii) the equilibrating mechanisms (the closures) for macro balances, factor markets, and markets for exports and imports. In this section, we apply the set of assumptions described in Table A-1.

Table. A-1: Model Simulation Assumptions

|  |  |
| --- | --- |
| Government budget:  | The government balance is cleared by adjustments in government investment in the context of rule-based or exogenous levels for other government payments (including exogenous values for tax rates, quantities of government consumption, and foreign and domestic financing). |
| Savings-investment:  | The level of domestically financed private investment is determined by the level of financing from domestic non-government institutions, for which the marginal propensities to save are fixed. Government investment is financed as part of the government budget. |
| Balance of payments:  | The balance is cleared by adjustments in the real exchange rate, which influence export and import quantities and values; other items in the balance of payments (including transfers, foreign investment, and net foreign financing) are exogenous or determined by other rules. |
| Factor markets: | Private capital is activity-specific (not mobile across activities), with an activity-specific market-clearing wage. |
| Other factors (including labor) are mobile across activities; unemployment is endogenous for selected factors (typically labor).  |
| Foreign markets for exports and imports. Both world export and import prices are exogenous (i.e., the small country assumption). |

Production and factors

The equations in this block are listed in Table A-2. They cover the determination of production by sector, demands for factors and intermediates, TFP, factor wages (or rents), unemployment, and factor incomes. To save space, in this mathematical statement, we only present the simplest possible production function. The activity levels (), which drive the level of commodity production by each activity, are a CES function of factor employment, scaled to account for the contribution of intermediate inputs (PRD1). Factor demands () are a function of the parameters of the production function, wages, and the price of value-added (i.e., the payment to factors per unit of the activity), in a setting where the producers maximize profits while taking prices and wages as given (PRD2). TFP by activity is a function of an exogenous trend parameter, a scaling parameter (which is typically endogenous for the base simulation but otherwise exogenous), ratios between current and base-year government capital stocks, and openness to trade as the ratio between (a) the sum of real exports and imports, and (b) real GDP (PRD3). The latter ratio is defined in Table A-3. In this equation, the impacts of government capital stocks and openness to trade are both captured by a constant-elasticity formulation.

Other variables related to production are determined by activity levels, other parameters, and prices. Intermediate demand () is a Leontief fixed-coefficient function of activity levels (PRD4). Likewise, commodity output levels () are driven by activity levels multiplied by fixed yield coefficients (), summed over all relevant activities (PRD5). Depending on the values of the yield coefficients, any commodity may be produced by more than one activity, and any activity may produce more than one commodity. The value-added price (), which appeared above in the factor demand functions (PRD2), is defined as the price (or revenue) per unit of activity () net of activity taxes and the intermediate input cost per activity unit (PRD6). For any activity, is the product of yields and unit producer prices, summed over all outputs (PRD7).

The treatment of factor markets is rich, making it possible for the analyst to select alternative assumptions with regard to mobility, unemployment, and supply growth. In this mathematical statement, we assume that (i) private capital is fully employed and activity-specific (with endogenous allocations of private capital created by new investment), and (ii) other factors (labor and natural resources, if any) are mobile and may or may not have endogenous unemployment (depending on a set definition). Other configurations were also possible.

Table A-2 shows the treatment of the markets for factors other than private capital, which is treated in Table A-6 given its links to investment and its special treatment of mobility. For non-labor factors, the unemployment (excess-capacity) rates are fixed (PRD8). For labor, wages are determined by a “wage curve”, which is a function of the base-year wage and the ratios between current and base-year values for the CPI (the numéraire, which in practice does not change) and the unemployment rate, , which is endogenous and raised to a negative elasticity (PRD9). For all factors, the activity-specific wage term () is fixed (PRD10) and, irrespective of whether unemployment is endogenous or not, the factor market equilibrium conditions state that total employment equals total supplies adjusted for unemployment (or excess capacity) (PRD11).

Given the above-stated treatment, the factor market equilibrium conditions (PRD11) are cleared via adjustments in the economy-wide wage variable (). For factors not in the set FUEND, the quantities supplied for employment (the RHS of PRD11) are fixed in any given period; given this, the full adjustment burden falls on the LHS and the quantities demanded (defined in equation PRD2). For factors in FUEND (often labor), the adjustment is shared between the demand and supply sides. For example, in the case of excess demand (in PRD11, LHS is larger than RHS), an increase in would simultaneously (i) reduce and the LHS value of PRD11 (via PRD2); (ii) reduce the unemployment rate ( via PRD8), thereby increasing the RHS value of PRD11.

Irrespective of market treatment, the total income for each factor (), including private capital, is the product of the two wage terms and quantities employed, summed over all activities, plus net factor transfers (or income) from abroad, adjusted for the exchange rate (PRD12).

Table. A-2: Equations for production and factors

|  |  |  |  |
| --- | --- | --- | --- |
| PRD-1 |  |  | Value added |
| PRD-2 |  |  | Factor demands |
| PRD-3 |  |  | Total factor productivity |
| PRD-4 |  |  | Intermediate demands |
| PRD-5 |  |  | Output |
| PRD-6 |  |  | Value-added price |
| PRD-7 |  |  | Activity price |
| PRD-8 |  |   | Exogenousunemployment rates  |
| PRD-9 |  |  | Wage curve |
| PRD-10 |  |  | Exogenous activity-specific wage term for mobile factors |
| PRD-11 |  |  | Factor markets |
| PRD-12 |  |  | Factor income  |

Domestic and aggregate foreign trade

Tables A1-3 cover the allocation of domestic commodity demands between imports and domestic output and the allocation of domestic output between exports and domestic sales. Equations TRD1-TRD3 are related to prices. In TRD1, the export price received by producers, , is defined as the world export price, transformed into domestic currency via the exchange rate, and adjusted for export taxes and transactions (trade and transport) cost per unit of exports; the unit transaction cost is defined as the product of an input coefficient () and the input price, summed over all inputs. Similarly, equation TRD2 defines the domestic currency import price for demanders, , on the basis of the world import price, exchange rate, and import tariffs, in this case with the unit transaction cost added to the price. In both equations, it is assumed that the modeled economy is small; thus, world prices for exports and imports ( and ) are exogenous. Equation TRD3 links the demander and supplier prices for domestic output sold domestically, and : the demander price is defined as the supplier price plus the transaction cost per unit of domestically sold output, as will be discussed below, either of these prices can be seen as the market-clearing price for this category of outputs (cf. equation INV3).

The commodity demand, , is a CES aggregation of imports and domestic purchases, named the Armington function after its originator (TRD4); is referred to as a “composite” demand given that it is met from different sources. Equation TRD5 defines the composite demand for commodities that (as opposed to those covered by TRD4) do not have both imports and domestic purchases.

For commodities with both sources, domestic demanders are assumed to minimize the cost of any composite demand quantity subject to the Armington function and subject to the relative prices. The first-order conditions (FOCs) are made up of the Armington function itself (TRD4) and an equation that specifies the optimal demand ratio () as a function of the ratio between the prices of domestic output and imports () (TRD6). The composite price is implicitly defined by TRD7, given that the other variables in this equation are determined by other relationships. At the composite commodity level, a distinction is made between and . As shown by TRD8, the distinction is that (the price paid by domestic demanders) is adjusted to account for sales taxes, value-added taxes, and subsidies; given that both value-added taxes and subsidies always or often have different rates for different demander categories, is disaggregated along this additional dimension, captured by the index d.

On the production side, a constant-elasticity-of-transformation (CET) function defines the frontier for allocations of domestic output (, defined in the preceding section) between exports and domestic sales ( and , respectively) (TRD9) for outputs that, according to base data, have non-zero values for both destinations. Equation TRD10 defines the equivalent of this transformation for outputs with only domestic sales or exports.

For outputs with both destinations, producers are assumed to maximize the revenue of any output quantity subject to the CET function and relative prices. The FOCs are composed of the CET function and an equation that specifies the optimal supply ratio () as a function of the ratio between the prices of exports and domestic sales () (TRD11). The average producer output price, , is defined as the weighted average of the prices received for domestic sales and exports (TRD12). (In section A1.1, influences production decisions and revenues.) The demand for trade and transport services is a function of real domestic and foreign trade volumes using a fixed-coefficient formulation (TRD-13). The final two equations in this block define the real trade-GDP ratio and real GDP, which is the denominator of this ratio (TRD-14 and TRD-15).

Table. A-3: Equations for domestic and aggregate foreign trade

|  |  |  |  |
| --- | --- | --- | --- |
| TRD-1 |  |  | Export price |
| TRD-2 |  |  | Import price |
| TRD-3 |  |  | Domestic demand price for domestic output |
| TRD-4 |  |  | Composite demand if use of imports and domestic output |
| TRD-5 |  |  | Composite demand if not use of both imports and domestic output |
| TRD-6 |  |  | Import-domestic demand ratio |
| TRD-7 |  |  | Composite demand price |
| TRD-8 |  |  | Adjusted composite demand price |
| TRD-9 |  |  | Output transformation if both exports and domestic sales |
| TRD-10 |  |  | Output transformation if not both exports and domestic sales |
| TRD-11 |  |  | Export-domestic sales ratio |
| TRD-12 |  |  | Producer output price |
| TRD-13 |  |  | Trade and transport margin demands |
| TRD-14 |  |  | Real trade-GDP ratio |
| TRD-15 |  |  | Real GDP at market prices |

Current payments by domestic institutions

This equation block explains payments from the current accounts of domestic institutions, that is, current income and spending for households, the government, and enterprises. In the model and its database, at least one household must be included, and in practice, models applied to countries invariably have a government. Enterprises are optional Even though the model and the database can handle multiple representative households, this mathematical statement assumes for simplicity that there is only one household. The sets for institutions distinguish between INSD (all domestic institutions), INSDNG (all non-government domestic institutions; i.e., households and enterprises), and H (households, which may include “non-profit institutions in service of households’). Enterprises differ from households in that they are not consumed.

On the income side, the shares of domestic institutions in factor incomes (SHIF) are defined based on their stock (or endowment) shares (INS1); the stocks (QFINS) are defined below in Section 4.5. The factor incomes of domestic institutions, , are a function of these shares, factor incomes () net of direct taxes, and exogenous payments of factor incomes to the outside world (INS2). ( is defined in Section A1.1.) Using this information, the total income of domestic non-government institutions, , is the sum of factor incomes, transfers from the government (indexed to the numéraire, in this case, the CPI), transfers from abroad, and transfers from other institutions in INSDNG (INS3). (Government income is defined in a separate equation).

The values for consumption and transfer spending by domestic non-government institutions are defined after deducting payments for direct taxes and savings. The mathematical statement treats direct tax rates as exogenous (policy-determined) but demonstrates alternative treatments for savings rates. The marginal propensity to save, , is the product of an institution-specific rate (which may change over time) and a scaling parameter (INS4). If the latter is flexible, then total savings are adjusted endogenously in the context of restrictions on the total quantity or value of private investment financed by domestic non-government institutions. Here, the scaling parameter is fixed, meaning that investment spending must be flexible. (This is discussed in Section A1.5) Institution-specific savings values, , are a linear function of and income net of direct taxes, with an optional (non-zero) intercept, which is indexed to the numéraire (INS5). The presence of an intercept is essential when base-year data indicate that some household groups have negative savings – without a separate (and negative) intercept and the related assumption that marginal and average savings rates differ, higher incomes would in this setting reduce savings further below zero. Transfers from institutions in INSDNG to other institutions (in INS), , are fixed shares of their income net of direct taxes and savings (INS6). For households, consumption spending, , is defined as income net of direct taxes, savings, and transfers to other institutions (INS7). Household consumption demands, , are a function of population, prices, and total spending () (INS8), which are derived from the maximization of a Stone-Geary utility function subject to the total spending and prices. It is referred to as a linear expenditure system (LES) because spending on any commodity (the product of price and quantity) is a linear function of EH, which is evident if one multiplies both sides of INS8 by the price variable ().

The remaining equations in this block define the current government receipts and spending. Government receipts, , are the sum of tax revenues, domestic and foreign transfers, and factor income (INS9). Domestic transfers are exogenous and indexed to the numéraire; foreign transfers are exogenous in the FCU. The taxes are made up of direct taxes on institutions and factors, domestic indirect taxes on sales, value-added, activity revenues, export taxes, and import tariffs. To make the mathematical statement more easily digestible, value-added taxes (VATs) () are defined in a separate equation (INS10). Whether a given tax is part of an application depends on the database. As indicated, the VAT rates are disaggregated by commodity demand, demander, and period.

Current government spending, , is the sum of spending on consumption, domestic transfers, transfers abroad, and subsidies (INS11). The quantities of government consumption, , are defined based on a trend term () that may be scaled selectively (by commodity and period) (INS12), and the impact of a given value for the scaling variable depends on the level of the parameter – as indicated by its name; we propose that it be set between 0 and 1. In the current mathematical statement, is exogenous; if it is endogenous, it can be used to clear the government budget. Subsidy spending, , is also defined in a separate equation (INS13); subsidy rates are similar to VAT rates in that they are disaggregated by commodity, demander, and period.

Table. A-4. Equations for current payments by domestic institutions

|  |  |  |  |
| --- | --- | --- | --- |
| INS-1 |  |  | Shares of factor incomes to domestic institutions |
| INS-2 |  |   | Factor income to domesticinstitutions |
| INS-3 |  |  | Non-gov’t institution income |
| INS-4 |  |  | Marginal propensity to save |
| INS-5 |  |  | Non-gov’t institution savings |
| INS-6 |  |   | Institutional transfers |
| INS-7 |  |   | Household consumption expenditure  |
| INS-8 |  |  | Household consumption demand |
| INS-9 |  |  | Government current receipts |
| INS-10 |  |  | VAT revenue |
| INS-11 |  |  | Government expenditure |
| INS-12 |  |  | Government consumption  |
| INS-13 |  |  | Commodity subsidy |

Emissions

LPSM is structured to include any number of GHG emissions (indexed by ghg) generated through production processes and by final users of goods and services, such as household fuelwood and resulting emissions. For both, the quantity of emissions (measured in carbon dioxide equivalents to permit aggregation across GHGs) is the product of emission coefficients and consumption quantities. This basic definition of emissions provides a starting point for different extensions. Equations EM1 and EM2 determine the level of emissions from the intermediate and final demand, respectively. Equation EMI3 determines the level of emissions per unit of factor. In livestock, this could pertain to the size of the herds (for example, for methane emissions), and in agriculture, it could be linked to land use. The χ parameters allow for (exogenous) changes in the emission coefficients that could be brought about by autonomous improvements in the level of emissions per unit of use. From equations EM1-EMI3, it is straightforward to define (and report) different GHG emission indicators (such as total emissions and emissions disaggregated in different ways, by type of gas and emitter, or defined per unit of GDP). Targets for such indicators may be imposed at the same time as a policy tool (e.g., an emissions tax).

Table. A-5: Equations for emissions

|  |  |  |  |
| --- | --- | --- | --- |
| EMI-1 |  |  | Emissions from intermediate consumption |
| EMI-2 |  |  | Emissions from household consumption |
| EMI-3 |  |  | Emissions from factor use |

Investment, system constraints, and numéraire

This block covers investment spending by different institutions, how it is financed, and how the new capital generated feeds into the economy. The specification of investment and its financing makes it possible to specify the remaining system constraints, the markets for private capital factors, commodity balances, and the balance of payments. In addition, we specify the number required for CGE models like LPSM.

For the government, investment spending (or gross capital formation), INVG, is defined as the sum of government savings (the difference between current receipts and spending), domestic net financing (indexed to the numéraire), and foreign net financing (exogenous in FCU) (INV1). The sum of the two financing terms is the primary government deficit. These two terms are referred to as net financing items because they represent the difference between new borrowing and interest payments; the latter do not appear explicitly in the model. For domestic non-government institutions, the corresponding variable, INV, is the sum of savings and net financing from abroad minus claims on investment funding to finance the government and add to foreign reserves (INV2). Before translating investment spending into quantities of new capital, it is necessary to specify prices; in equation INV3, where the unit prices of new capital stocks, PK, are defined as the product of the price of commodity c and the matrix of capital composition coefficients (which shows the quantities of commodities c used as inputs per unit of any new capital stock f) summed over all c.

The next three equations define investment quantities by destination (by type of capital stock) by government and non-government institutions and investment quantities by source (the use of commodity inputs in the production of new capital). For the government, the quantity of new capital stock f, DKINSgov,f,t, is defined as the investment spending net of spending on new inventory (gross fixed capital formation or GFCF), multiplied by the spending share for f, and divided by PK to transform into stock quantities (INV4). In the corresponding equation for non-government investment (INV5), GFCF is the sum of (a) investment net of stock change spending for institutions in INSDNG; (b) foreign investment (the value of which is exogenous in FCU). GFCF is allocated across different capital stocks (if more than one) in fixed spending shares and transformed into quantities of new capital by dividing by PK. Final investment demands (i.e., investment quantities defined by the source of inputs into the construction of new capital), QINV, are defined as the product of the capital composition matrix and investment by capital stock, summed over all capital stocks (INV6).

For any capital stock, the endowments held by domestic institutions (government and non-government), QFINS, are defined as the sum of (a) the stock held in the previous year’s net of depreciation, and (b) new investment in the previous year (INV7). Endowments are defined exogenously (INV8) for stocks of other factors.

The allocation of private capital stocks across activities responds to relative capital rents. As an input to the formulation used, the average wage of private capital stock f, WFAVG, is defined as the total rent to f divided by the total employment of f (INV9). In equation INV10, the allocation of new private capital stock f to an activity a, DKA, is defined as the product of (a) an allocation based on current activity shares (i.e., total new investment in f times the current share of a in the use of f), and (b) an adjustment term that is above (below) unity if the wage of capital stock f in a is above (below) the economy-wide average, assuming a positive value for the parameter κ (Greek kappa; κ ≥ 0). κ plays a crucial role in this formulation: the higher its value, the stronger the sensitivity of the allocation of new capital to differences in capital rents; if it is zero, the allocation of stock f does not change over time, and if it is too high, capital rents may oscillate.

Total employment of capital stock f in activity a in period t, QFf, a,t, is defined as the stock installed in t-1, QFf,a,t-1, net of depreciation, plus the quantity of new investment in stock f in t-1 allocated to a, DKAf,a,t-1 (INV11). This last equation may be seen as defining a set of activity-specific markets for capital stock f in which the quantity supplied (the right-hand side) is fixed within any period t (determined by past decisions), while the quantity demanded (the left-hand side) is determined by profit maximization. A wage variable defined over f and a is required to clarify this market. Accordingly, among the two wage variables that apply to any factor (WFf,t and WFDISTf,a,t), equation INV12 fixes the economy-wide variable WF while leaving the activity-specific variable WFDIST flexible. The simulated values for the product of the two variables show the scarcity value of private capital stocks by activity. In sum, for private capital, it is assumed that installed stocks cannot be reallocated, while the analyst controls the extent to which the allocation of new capital will shift toward sectors with relatively high capital rents.

For each domestic commodity, the demand side is complete. The equation INV13 defines the total composite demand for any commodity, QQ, as the sum of consumption, investment (fixed capital formation and stock changes), intermediate demands, and demands for trade and transportation services (due to domestic and foreign trade). As previously specified, these demands generate demand for domestic output and imports. The markets for domestic output sold domestically are cleared by the linked variables PDD and PDS. For example, in the case of excess demand, increases in both price variables would simultaneously reduce domestic demands for domestic outputs and increase the quantities of output sold domestically (raising the total output level by raising profitability and raising the share of output sold domestically).

The statement on investment financing completes the flows in the balance of payments expressed in the FCU. Equations INV14 and INV15 state the current and capital accounts, respectively, with foreign savings, SAVF, as the linking variable. In the current account balance, inflows are due to exports and transfers from abroad, while outflows are caused by imports, transfers from domestic non-government institutions, and factor incomes. The variable SAVF measures the current account deficit; if outflows (the right-hand side) are larger (smaller) than inflows (the left-hand side), foreign savings are positive (negative). In the capital account balance, the current account deficit is financed by net foreign financing to government and non-government institutions and foreign investment, net of increases in foreign reserves. By influencing export and import quantities in opposite directions, raising or reducing the trade balance in FCU, adjustments in the exchange rate, EXR, clear the balance of payments, ensuring that the level of foreign savings matches the level that is financed on the right-hand side of the capital account.

As a manifestation of Walras’ law, in a CGE model like the one presented above, one equation should be removed to ensure equality between the number of variables and independent equations; it is possible to check that the omitted equation holds in a post-calculation. Here, we opt for the alternative of substituting one variable, named WALRAS, into one equation. Hence, the presence of the WALRAS in the capital accounts of the balance of payments. In the absence of errors, the solution value for WALRAS should be (very close to) zero.

Finally, a well-specified CGE model such as LPSM is homogeneous of degree zero in prices, meaning that only relative prices matter and that, if one set of relative prices solves the model, then any multiple of this set of prices would also solve the model (scaling all domestic prices and payments) without any influence on quantities. To anchor the price level, a price or price index, referred to as the numéraire, needs to be fixed, with the consequence that all other prices are measured relative to this numéraire. In this mathematical statement, the consumer price index, CPI, is the numéraire. Here, equation INV16 defines the CPI, which is fixed based on the base-year weights of household consumption payments by commodity and household type in total household consumption.

Table. A-6: Equations for investment, system constraints, and numéraire

|  |  |  |  |
| --- | --- | --- | --- |
| INV-1 |  |  | Gov’t primary deficit, investment value, and financing |
| INV-2 |  |  | Non-gov’t investment value and its financing |
| INV-3 |  |  | Price of new capital |
| INV-4 |  |  | Gov’t investment by government capital stock |
| INV-5 |  |  | Non-gov’t investment by private capital stock |
| INV-6 |  |  | Real investment demand (by source) |
| INV-7 |  |  | Accumulation of capital by domestic institutions |
| INV-8 |  |  | Exogenous institutional endowments for other factors |
| INV-9 |  |  | The average wage (rent) by private capital stock |
| INV-10 |  |  | Allocation of new private capital by activity |
| INV-11 |  |  | Accumulation of private capital by activity |
| INV-12 |  |  | Exogenous economy-wide wage term for private capital  |
| INV-13 |  |  | Commodity balance |
| INV-14 |  |  | The current account of the balance of payments |
| INV-15 |  |  | The capital account of the balance of payments |
| INV-16 |  |  | Consumer price index |

# LPSM Notation

This section explains the notational principles designed to make it easy to understand the statement. Tables A-7 to A-11 define the model sets, variables, Latin-letter parameters, and Greek-letter parameters, respectively. In each of these tables, the items are arranged alphabetically.

Table A-7. Notational principles

|  |  |  |
| --- | --- | --- |
| Items | Notation | Example |
| Sets | Lower-case Latin letters as subscripts to variables and parameters | see the following rows |
| Endogenous variables | Upper-case Latin letters (without a bar)\* |  |
| Exogenous variables\*\* | Upper-case Latin letters with a bar\* |  |
| Parameters\*\* | Lower-case Latin letters\* or lower-case Greek letters (with or without superscripts) | ;  |

\*The names of Latin letter variables and parameters that refer to prices, quantities, and factor wages (rents) start with P, Q, and WF, respectively.

\*\*The distinction between exogenous variables and parameters is that the latter always have exogenous values whereas the former under alternative assumptions may be endogenous.

Table A-8. Sets

|  |  |
| --- | --- |
| Name | Description |
|  | activities (production sectors or industries) |
|  | commodities (i.e., goods and services) |
|  | commodities with domestic sales of domestic output |
|  | exported commodities |
|  | imported commodities |
|  | transactions commodities (services paid under distribution margins) |
|  | domestic demanders (or demand types): institutions (for consumption), investment by capital type, activities, transactions (distribution margins) |
|  | Factors |
|  | factors that earn value-added (in SAM) |
|  | capital factors |
|  | gov’t capital factors (do not earn value-added) |
|  | non-gov’t capital factors (earn value-added) |
|  | labor factors (earn value-added) |
|  | other factors (earn value-added; not capital or labor) |
|  | factors with an endogenous unemployment rate |
|  | greenhouse gases |
|  | institutions |
|  | domestic institutions |
|  | domestic non-government institutions |
|  | non-gov’t institutions (rest of world and elements in INSDNG) |
|  | Households |
|  | periods (simulation years) |
|  | base period (first simulation year) |
|  | transactions (distribution) types (domestic, import, export) |
|  | transactions (distribution) for domestic sales |
|  | transactions (distribution) for exports |
|  | transactions (distribution) for imports |

Table A-9. Variables

|  |  |
| --- | --- |
| Name | Description |
|  | consumer price index |
|  | change in capital stock f allocated to activity a  |
|  | investment by institution i (in INS) in capital stock f |
|  | domestic producer price index (PDS-based) |
|  | total current government expenditure |
|  | consumption expenditure for household h |
|  | emissions of ghg from commodity c by domestic demander d |
|  | exchange rate (local currency per unit of foreign currency |
|  | value of investment (including stock change) for institution i (in INSNG) |
|  | value of investment (including stock change) for government |
|  | marginal propensity to save for domestic non-government institution i (in INSDNG) |
|  | MPS scaling factor |
|  | net foreign financing of government (FCU) |
|  | net foreign financing for non-government institution i (in INSDNG) (FCU)  |
|  | output price for activity a |
|  | demand price for commodity c (in C) produced and sold domestically |
|  | supply price for commodity c (in C) produced and sold domestically |
|  | price for export of c (in C) (LCU) (net of export taxes and distribution margin) |
|  | price (per unit of) of capital stock f |
|  | price for import of c (in C) (LCU) (includes import tariffs and distribution margin) |
|  | composite commodity price for c (in C) for domestic demander (type) d (in D) [includes commodity subsidies, all taxes (including VAT and sales tax), and distribution margins] |
|  | composite commodity price for c (includes import tariffs and distribution margins but not a sales tax, commodity subsidies, or VAT) |
|  | producer price for commodity c |
|  | value-added price for activity a |
|  | level of activity a |
|  | quantity sold domestically of domestic output c |
|  | quantity of exports of commodity c (in C) |
|  | quantity demanded of factor f by activity a |
|  | the endowment of institution i (in INSD) of factor f  |
|  | quantity of government consumption of commodity c |
|  | government consumption scaling factor |
|  | the quantity consumed of commodity c by household h |
|  | quantity of commodity c as an intermediate input to activity a |
|  | quantity of investment demand for commodity c (investment by source) |
|  | investment scaling factor |
|  | quantity of imports of commodity c (in C) |
|  | quantity of composite demand (and supply) of commodity c (in C) |
|  | quantity of trade and transport services demand for commodity c (in C) |
|  | quantity of domestic output of commodity c (in C) |
|  | real GDP at market prices (at constant base-year prices) |
|  | foreign savings (FCU) |
|  | government savings |
|  | savings of domestic non-government institution i (in INSDNG) |
|  | share for institution i (in INSD) in the income of factor f |
|  | government spending on commodity subsidies |
|  | total factor productivity for activity a |
|  | scaling of total factor productivity |
|  | real foreign trade (exports+imports) and GDP ratio |
|  | transfers to institution i (in INS) from domestic non-government institution i’ (in INSDNG) |
|  | the unemployment rate for factor f  |
|  | variable check on Walras’ law (which is satisfied if the value is zero) |
|  | the economywide wage of factor f |
|  | the average wage for factor f (in FCAPNG) |
|  | wage distortion factor for factor f in activity a |
|  | income of factor f |
|  | government current revenue |
|  | income of (domestic non-government) institution i (in INSDNG) |
|  | income of institution i (in INSD) from factor f |

Table A-10. Latin letter parameters

|  |  |
| --- | --- |
| Name | Description |
|   | quantity of commodity c per unit of new capital stock f |
|  | weight of commodity c in consumption basked of household h |
|  | rate of depreciation for capital stock f |
|  | change in foreign reserves (FCU) |
|  | weight of commodity c in the DPI (PDS-based producer price index) |
|  | quantity of intermediate input c per unit of activity a |
|  | the input of c for trade and transportation per unit of commodity c’ produced and sold domestically |
|  | transactions input of c per unit of commodity c’ export |
|  | transactions input of c per unit of commodity c’ imports |
|  | share for capital stock f in investment spending of institution i (in INSNG) |
|  | emissions of ghg per unit demanded of commodity c by domestic demander d |
|  | baseline marginal propensity to save for domestic non-gov’t institution i (in INSDNG) |
|  | net domestic financing to government (indexed to numéraire) (FCU) |
|  | net foreign financing to institution i (in INSD) (FCU) [MC: should this one stay here or above with a bar on top in the equations?] |
|  | the population of ac (household h in H or country total) |
|  | export price for commodity c (in foreign currency) |
|  | import price for commodity c (in foreign currency) |
|  | change in stock (inventories) of c for institution i (in INSD) |
|  | endowment for institution i (in INSD) of factor f (in FOTH) |
|  | baseline quantity of government consumption of commodity c |
|  | 0-1 parameter turning on-off potential scaling of gov consumption of c |
|  | base-year quantity of investment (GFCF) demand for c |
|  | share of institution i (in INS) in the income (net of direct taxes and savings) of domestic non-gov’t institution i’ (in INSDNG) |
|  | rate of subsidy on commodity c (in C) for demander d (in D) |
|  | rate of tax on gross output value for activity a |
|  | rate of tax on commodity c |
|  | rate of a direct tax on factor f |
|  | exogenous component of TFP for activity a |
|  | rate of import tariff on commodity c |
|  | rate of sales tax on commodity c |
|  | transfers from institution i (gov’t or rest of world) to ac [where ac is institution i (in INS) or factor f (in F)](LCU if from gov’t; FCU if from rest of world) |
|  | rate of value-added tax on commodity c (in C) for demander d (in D) |
|  | rate of a direct tax on domestic non-gov’t institution i (in INSDNG) |
|  | the exogenous unemployment rate for factor f (not in FUEND) |
|  | exogenous economywide wage term for activity-specific factors |
|  | exogenous activity-specific wage term for mobile factors |

Table A-11. Greek letter parameters

|  |  |
| --- | --- |
| Name | Description |
|  | intercept in savings function for institution i (in INSDNG) |
|  | share parameter in LES function for household consumption of commodity c |
|  | minimum quantity in LES function for household consumption of commodity c |
|  | share parameter for domestic purchases in Armington function for commodity c (top of the nest) |
|  | share parameter for domestic sales in CET function for commodity c (top of the nest) |
|  | share parameter for exports in CET function for aggregated commodity c (in C) (top of the nest) |
|  | share parameter for imports in Armington function for commodity c (top of the nest) |
|  | share parameter for factor f in CES VA function for activity a |
|  | the elasticity of TFP in activity a with respect to gov’t capital stock f |
|  | the elasticity of wage for factor f (in FUEND) with respect to the unemployment rate |
|  | yield of output c per unit of activity a |
|  | sensitivity of the allocation of new capital for f (in FCAPNG) across activities (in A) to current deviations of activity capital rents from the economywide average |
|  | the exponent in Armington function for commodity c |
|  | the exponent in CES VA function for activity a |
|  | the exponent in CET function for commodity c (top of the nest) |
|  | the elasticity of substitution between supplies of domestic output and imports in Armington function for c (top of the nest) |
|  | the elasticity of substitution between factors in CES VA function of activity a |
|  | the elasticity of transformation between domestic sales and exports in CET function for c (top of the nest) |
|  | shift parameter in Armington function in which domestic sales and imports of commodity c (in C) are aggregated to composite supply (top of the nest) |
|  | shift parameter for CES VA function of activity a |
|  | shift parameter in CET function for commodity c (top of the nest) |

Appendix B

Figure B-1: Production technology in the livestock sectors

