
Appendix B

Algebraic Specification of the Model

This appendix provides a detailed mathematical specification of the 20-region, 32-sector recursive dynamic computable general equilibrium (CGE) model for world production and trade used in this study (see tables B.1 and B.2). The structures of production and consumption as well as the price system in the model are illustrated in figures B.1 to B.3.

Notation

- Regions are defined in set R and indexed by r or s
- Sectors are defined in set I and indexed by i or j
- Agricultural sectors are defined as a subset of I : $IAG(I)$
- Natural-resource-based sectors are defined as a subset of I : $RES(I)$
- Primary factors are defined in set F and indexed by f .

Conventions

An uppercase English letter indicates variables, unless they have a bar on top, in which case that variable is always set exogenously. A Greek letter or lowercase English letter refers to parameters, which need to be calibrated or supplied from exogenous sources. When multiple subscripts of

a variable or parameter come from the same set, the first one represents the region or sector supplying goods; the next represents the region or sector purchasing goods (see tables B.3 and B.4).

Price Equations

Equations 1–11 are price equations in the model. Equations 1 and 2 define the relationship between border (world) prices and internal prices, while equations 3–8 define price indices for aggregate imported goods, Armington goods, composite value added, and the firm's output with and without production taxes, respectively. In equations 3–7, the price indices are the unit cost functions, while in equation 8 they are unit revenue functions, all of which are dual to the corresponding unit quantity aggregator functions. For example, equation 7 is the result of cost minimization by the representative firm in each sector with respect to its aggregate factor and inputs, subject to a constant elasticity of substitution (CES) production function. Since CES functions are used as the building blocks of the basic model, and this quantity aggregator function is homogeneous of degree 1, the total costs can be written as total quantity multiplied by unit cost (Varian 1984, 28). This implies that the average cost, under cost minimization, is independent of the number of units produced or purchased. Thus, the unit cost function also stands for the price of the composed commodity. Equation 5 defines the unit price for aggregate inputs, which is the input-output (IO) coefficient weighted sum of all the value of its contents. Equation 9 states that the domestic consumer price is the Armington goods price plus sales taxes. Equation 10 specifies an economy-wide consumer price index, which is used as the price of household savings. Equation 11 defines the numeraire in the model.

$$PWM_{isr} = (1 + trs_{isr}) \times PWE_{isr} \quad (1)$$

$$PWE_{isr} = (1 + te_{isr}) \times \left(\frac{1}{ER_r}\right) \times PE_{ir} \quad (2)$$

$$PM_{ir} = \frac{1}{\mu_{ir}} \times \left\{ \sum_{s \in R} \xi_{irs}^{\sigma_i} \times [(1 + tm_{irs} + tn_{irs}) \times ER_r \times PWM_{irs}]^{1-\sigma_i} \right\}^{\frac{1}{1-\sigma_i}} \quad (3)$$

$$PX_{ir} = \frac{1}{\Gamma_{ir}} \times \left\{ \sum \alpha_{ir}^{\sigma_i} \times PD_{ir}^{1-\sigma_i} + (1 - \alpha_{ir})^{\sigma_i} \times PM_{ir}^{1-\sigma_i} \right\}^{\frac{1}{1-\sigma_i}} \quad (4)$$

$$PN_{jr} = \sum_{i \in I} io_{ijr} \times PX_{ir} \quad (5)$$

$$PV_{ir} = \frac{1}{\Lambda_{ir} \times tff_p \times ITFP_{ir}} \times \left\{ \sum_{f \in F} \delta_{fir}^{\sigma_i} \times PF_{fr}^{1-\sigma_i} \right\}^{\frac{1}{1-\sigma_i}} \quad (6)$$

$$PP_{ir} = \frac{1}{A_{ir}} \times \{ \lambda_{ir}^{\sigma_{pi}} \times PN_{ir}^{1-\sigma_{pi}} + (1-\lambda_{ir})^{\sigma_{pi}} \times PV_{ir}^{1-\sigma_{pi}} \}^{\frac{1}{1-\sigma_{pi}}} \quad (7)$$

$$P_{ir} = \frac{1}{\chi_{ir}} \times \{ \kappa_{ir}^{\sigma_{ei}} \times PD_{ir}^{1-\sigma_{ei}} + (1-\kappa_{ir})^{\sigma_{ei}} \times PE_{ir}^{1-\sigma_{ei}} \}^{\frac{1}{1-\sigma_{ei}}} \quad (8)$$

$$PC_{ir} = (1 + tc_{ir}) \times PX_{ir} \quad (9)$$

$$CPI_r = \frac{\sum_{i \in I} PC_{ir} \times C_{ir}}{\sum_{i \in I} PCO_{ir} \times C_{ir}} \quad (10)$$

$$PID_r = \prod_{i \in I} PC_{ir}^{\beta_{ir}} \times CPI_r^{mps_r} \quad (11)$$

Factor Demand and Firms' Supply Equations

Equations 12 and 13 specify the demand functions for aggregate factor and intermediate inputs, while equation 14 gives demand functions of each primary factor. They equal unit demand function multiplied by the quantities of total output, and the unit demand functions are obtained by taking partial derivatives of the unit cost functions (equations 6 and 7) with respect to the relevant factor prices, according to Shephard's lemma.

$$NX_{ir} = \left(\frac{1}{A_{ir}} \right)^{1-\sigma_{pi}} \times (\lambda_{ir} \times \frac{PP_{ir}}{PN_{ir}})^{\sigma_{pi}} \times Q_{ir} \quad (12)$$

$$VA_{ir} = \left(\frac{1}{A_{ir}} \right)^{1-\sigma_{pi}} \times [(1-\lambda_{ir}) \times \frac{PP_{ir}}{PV_{ir}}]^{\sigma_{pi}} \times Q_{ir} \quad (13)$$

$$DF_{fir} = \left(\frac{1}{\Lambda_{ir} \times tfp_r \times ITFP_{ir}} \right)^{1-\sigma_{vi}} \times (\delta_{fir} \times \frac{PV_{ir}}{PE_{fir}})^{\sigma_{vi}} \times VA_{ir} \quad \sum_{f \in F} \delta_{fir} = 1 \quad (14)$$

Equations 15–18 are the domestic and export supply functions corresponding to the constant elasticity of transformation (CET) function commonly used in today's CGE models. They are derived from revenue maximization, subject to the CET function, in a way similar to the derivation of factor demand functions. Equation 19 aggregates exports by the representative firm in each region, which implies that producers only differentiate output sold in domestic and foreign markets, but do not differentiate exports by destination (foreign markets are perfect substitutes). Equations 15–18 can be partially or entirely turned off in the model; in such case, $PD_{ir} = PE_{ir} = P_{ir}$ will be enforced and exports and domestic sales become perfect substitutes in the model.

$$DX_{sv,r} = \left(\frac{1}{\chi_{sv,r}}\right)^{1-\sigma_{sv}} \times (\kappa_{sv,r} \times \frac{P_{sv,r}}{PD_{sv,r}})^{\sigma_{sv}} \times (Q_{sv,r} - TRQS_r) \quad (15)$$

for $s \neq sv$

$$DX_{ir} = \left(\frac{1}{\chi_{ir}}\right)^{1-\sigma_{ir}} \times (\kappa_{ir} \times \frac{P_{ir}}{PD_{ir}})^{\sigma_{ir}} \times Q_{ir} \quad (16)$$

$$EX_{sv,r} = \left(\frac{1}{\chi_{sv,r}}\right)^{1-\sigma_{sv}} \times \{(1-\kappa_{sv,r}) \times \frac{P_{sv,r}}{PE_{sv,r}}\}^{\sigma_{sv}} \times (Q_{sv,r} - TRQS_r) \quad (17)$$

for $s \neq sv$

$$EX_{ir} = \left(\frac{1}{\chi_{ir}}\right)^{1-\sigma_{ir}} \times \{(1-\kappa_{ir}) \times \frac{P_{ir}}{PE_{ir}}\}^{\sigma_{ir}} \times Q_{ir} \quad (18)$$

$$EX_{ir} = \frac{1}{PE_{ir}} \times \sum_{s \in K} \frac{ER_s}{(1+te_{irs})} \times PWE_{irs} \times X_{irs} \quad (19)$$

Trade and Final Demand Equations

Trade and final demand equations are listed in equations 20–26. Equation 20 is the consumer demand function, which is the ELES derived from maximizing a Stone-Geary utility function subject to household disposable income, which is specified in equation 31. Equation 21 defines household supernumerary income, which is disposal income less total expenditure on the subsistence minimum. Equations 22 and 23 give government and investment demands. Equations 24–26 are demand functions for domestic goods, aggregate imported goods, and imported goods by source, respectively. They describe the cost-minimizing choice of domestic and import purchases, as well as import sources. They are derived from corresponding cost functions according to Shephard’s lemma in a way similar to the derivation of factor demand functions (taking partial derivatives of the cost function with respect to the relevant component prices). Because of the linear homogeneity of the CES function, the cost function that is dual to the commodity aggregator can be represented by its unit cost function (equations 3 and 4) multiplied by total quantity demanded.

$$C_{ir} = \gamma_{ir} + \frac{\beta_{ir}}{PC_{ir}} \times SY_r \quad (20)$$

$$SY_r = HDI_r - \sum_{j \in I} PC_{jr} \times \gamma_{jr} \quad (21)$$

$$GC_{ir} = \frac{\theta_{ir}}{PC_{ir}} \times GSP_r \quad (22)$$

$$ID_{ir} = \frac{kio_{ir}}{PC_{ir}} \times INV_r \quad (23)$$

$$DX_{ir} = \left(\frac{1}{\Gamma_{ir}}\right)^{1-\sigma_{m_i}} \times (\alpha_{ir} \times \frac{PX_{ir}}{PD_{ir}})^{\sigma_{m_i}} \times TX_{ir} \quad (24)$$

$$MX_{ir} = \left(\frac{1}{\Gamma_{ir}}\right)^{1-\sigma_{m_i}} \times \{(1-\alpha_{ir}) \times \frac{PX_{ir}}{PM_{ir}}\}^{\sigma_{m_i}} \times TX_{ir} \quad (25)$$

$$X_{isr} = \left(\frac{1}{\mu_{ir}}\right)^{1-\sigma_i} \times \{\xi_{isr}\} \times \left(\frac{PM_{ir}}{(1+tm_{isr}+tn_{irs}) \times ER_r \times PWW_{isr}}\right)^{\sigma_i} \times MX_{ir} \quad \sum_{s \in R} \xi_{isr} = 1 \quad (26)$$

for $s \neq r$

International Shipping Equations

Equations 27–30 describe the international shipping industry in the model. Equations 27 and 28 describe the supply side of the international shipping industry. Equation 27 states that at equilibrium, the returns from shipping activity must cover its cost. Like other industries in the model, it also earns zero profit. Equation 28 describes the demand for each region's services sector exports to the international shipping industry, which is generated by the assumed Cobb-Douglas technology in this industry. The next two equations (29 and 30), refer to the demand side of the international shipping industry. The demand for shipping services associated with commodity i in region r is generated by a fixed-proportion input requirement (Leontief) coefficient trs_{isr} which is routine/commodity specific (equation 29). In equilibrium, the total demand of shipping service must equal its total supply (equation 30).

$$TRQ = \frac{1}{PTR} \times \sum_{r \in R} \frac{P_{sv,r}}{ER_r} \times TRQS_r \quad (27)$$

$$TRQ = \sum_{r \in R} \sum_{i \in I} TRQD_{ir} \quad (28)$$

$$TRQS_r = \frac{\tau_r \times ER_r}{P_{sv,r}} \times PTR \times TRQ \quad (29)$$

$$TRQD_{ir} = \frac{1}{PRT} \times \left(\sum_{s \in R} trs_{isr} \times PWE_{isr} \times X_{isr}\right) \quad (30)$$

Income and Saving Equations

Equations 31–39 are income and saving equations in the model. Equations 31 and 32 define household disposal income and savings. Equations 33–37

determine government revenue from production taxes, consumption taxes, tariffs, and export taxes (its negative equals a subsidy), respectively, while equations 38–39 define government transfers to household and the balance of trade (foreign savings) in each region.

$$HDI_r = \sum_{f \in F} PF_{fr} \times \overline{FS}_{fr} - dk_r \times \overline{FS}_{KAr} + GTRANS_r \quad (31)$$

$$GR_r = PTAX_r + CTAX_r + TARRIF_r + ETAX_r \quad (32)$$

$$SAV_r = \frac{HDI_r \times \sum_{i \in I} PC_{ir} \times C_{ir}}{CPI_r} \quad (33)$$

$$PTAX_r = \sum_{i \in I} tp_{ir} \times P_{ir} \times Q_{ir} \quad (34)$$

$$CTAX_r = \sum_{i \in I} tc_{ir} \times PX_{ir} (C_{ir} + GC_{ir} + ID_{ir}) \quad (35)$$

$$TARRIF_r = \sum_{s \in R} \sum_{i \in I} (tm_{isr} + tn_{irs}) \times ER_r \times PWM_{isr} \times X_{isr} \quad (36)$$

$$ETAX_s = \sum_{r \in R} \sum_{i \in I} te_{isr} \times PE_{is} \times X_{isr} \quad (37)$$

$$GTRANS_r = GR_r - GSP_r - GSVA_r \quad (38)$$

$$BOT_r = \sum_{s \in R} \sum_{i \in I} PWE_{irs} X_{irs} + \frac{P_{sv,r}}{ER_r} \times TRQS_r - \sum_{s \in R} \sum_{i \in I} PWM_{isr} \times X_{isr} \quad (39)$$

General Equilibrium Conditions

Equations 40–43 define general equilibrium conditions of the model, which are system constraints that the model economy must satisfy. For every sector in each region, the supply of the composite goods must equal total demand (equation 40), which is the sum of household consumption (C_{ir}), government purchases (GC_{ir}), investment (ID_{ir}), and the firm's intermediate demand. Similarly, the demand for each factor in every region must equal the exogenously fixed supply (equation 41). In this dual formulation, output in each region is determined by demand. Sectoral equilibrium is determined in equation 42, unit output price equals average cost, which is also the zero profit condition. Equation 43 describes the macroeconomic equilibrium identity in each region, which is also the budget constraint for the investor. Since all agents in each region (house-

holds, governments, investors, and firms) satisfy their respective budget constraints, it is well known that the sum of the excess demand for all goods is zero; that is, Walras's law holds for each region. Therefore, there is a functional dependence among the equations of the model. One equation is redundant in each region and thus can be dropped.

$$TX_{ir} = C_{ir} + GC_{ir} + ID_{ir} + \sum_{j \in I} io_{ijr} \times NX_{jr} \quad (40)$$

$$\sum_{i \in I} DF_{fir} = \overline{FS}_{fr} \quad (41)$$

$$P_{ir} = \frac{PN_{ir} \times NX_{ir} + PV_{ir} \times VA_{ir} + tp_{ir} \times P_{ir} \times Q_{ir}}{Q_{ir}} \quad (42)$$

$$INV_r = dr_r \times \overline{FS}_{k,r} + CPI_r \times (SAV_r + GSAV_r) - ER_r \times BOT_r \quad (43)$$

There are 52,402 equations and 52,582 variables in each of the intraperiod blocks of the model. Since the 120 factor endowment variables (FS_r) are determined by the initial stock and interperiod linkage equations, three additional sets of variables (60) have to be set exogenously as macro closures in order to make the model fully determinate. They are chosen from following variables for alternative closures: (1) gross investment or government transfer (INV_r or $GTRANS_p$); (2) balance of trade or exchange rate (BOT_r or ER_p); and (3) government spending or surplus (deficit) (GSP_r or $GSAV_p$).

Interperiod and Trade-Productivity Linkages

Equations 44–48 define the recursive structure of the five types of factor endowments (natural resources are sector specific and held constant, and they can be modified if more reliable data become available in the modeled economy). For instance, capital stock in each region at period t equals the last period's capital stock plus the region's gross investment minus depreciation. Unskilled labor equals last period's employment multiplied by population growth rate, plus rural-urban migration, MIG_{rt} , minus the increase of skilled labor SK_{rt} (set exogenously).

$$FS_{KAr,t} = (1 - dk_r) \times FS_{KAr,t-1} + INV_{rt} \quad (44)$$

$$FS_{SLr,t} = (1 + n_{rt}) \times FS_{SLr,t-1} + ds_r \times \overline{VSK}_{rt} \quad (45)$$

$$FS_{ULr,t} = (1 + n_{rt}) \times FS_{ULr,t-1} + MIG_{rt} - ds_r \times \overline{VSK}_{rt} \quad (46)$$

$$FS_{RLr,t} = (1 + n_{rt}) \times FS_{RLr,t-1} - MIG_{rt} \quad (47)$$

$$FS_{LDr,t} = (1 - dl_t) \times FS_{LDr,t-1} \quad (48)$$

Equation 49 links import-embodied technology transfer (via imports of capital goods and intermediate inputs) and TFP. Where $X0_{jsr}$ is the base year real trade flows, IM is a subset of I , including those products embodied with advanced technology. It operates through share parameter and elasticities. An elasticity (ip_{ir}) of 0.1 implies that a 10 percent increase in real imports of capital- and technology-intensive goods would result in no more than a 1 percent increase in TFP in that sector, depending on the share of intermediate inputs in the sector's total imports. As pointed out by Lewis, Robinson, and Wang (1995), while there is fairly widespread agreement that linkage between imports of intermediate inputs and productivity gains do exist, there is less evidence of the size of the feedback. In our simulation exercises, the elasticities used for developed countries are at least less than half the values used for the developing countries.

$$ITFP_{ir} = 1 + im_{s_{ir}} \times \left\{ \frac{NX_{ir}}{NX_{ir} + VA_{ir}} \times \left[\frac{\sum_{j \in IM} \sum_{s \in R} x_{jsr}}{\sum_{j \in IM} \sum_{s \in R} x0_{jsr}} \right]^{\sigma ip_{ir}} + \frac{VX_{ir}}{NX_{ir} + VA_{ir}} - 1 \right\} \quad (49)$$

Table B.1 Model regions, Global Trade Analysis Project (GTAP) region codes, and country name concordance

| Model regions | Country name | GTAP region code | |
|----------------------|--|-------------------------|-----|
| China | China | CHN | |
| Taiwan | Taiwan | TWN | |
| Hong Kong | Hong Kong | HKG | |
| Indonesia | Indonesia | IDN | |
| Japan | Japan | JPN | |
| Korea | Korea, Republic of | KOR | |
| Malaysia | Malaysia | MYS | |
| Philippines | Philippines | PHL | |
| Singapore | Singapore | SGP | |
| Thailand | Thailand | THA | |
| United States | United States of America | USA | |
| Vietnam | Vietnam | VNM | |
| Rest of East Asia | Cambodia | KHM | |
| | Lao People's Democratic Republic | LAO | |
| | Myanmar | MMR | |
| | Macau | XEA | |
| | Mongolia | | |
| | Korea, Democratic People's Republic of | | |
| | Brunei Darussalam | XSE | |
| | Timor Leste | | |
| | Australia and New Zealand | Australia | AUS |
| | | New Zealand | NZL |
| South Asia | Bangladesh | BGD | |
| | India | IND | |
| | Sri Lanka | LKA | |
| | Pakistan | PAK | |
| | Afghanistan | XSA | |
| | Bhutan | | |
| | Maldives | | |
| | Nepal | | |
| EU-12 | Bulgaria | BGR | |
| | Cyprus | CYP | |
| | Czech Republic | CZE | |
| | Estonia | EST | |
| | Hungary | HUN | |
| | Lithuania | LTU | |
| | Latvia | LVA | |
| | Malta | MLT | |
| | Poland | POL | |
| | Romania | ROM | |
| | Slovakia | SVK | |
| | Slovenia | SVN | |
| EU-15 | Austria | AUT | |
| | Belgium | BEL | |
| | Germany | DEU | |
| | Denmark | DNK | |
| | Spain | ESP | |

(continued on next page)

Table B.1 Model regions, Global Trade Analysis Project (GTAP) region codes, and country name concordance *(continued)*

| Model regions | Country name | GTAP region code |
|----------------------|-----------------------|------------------|
| | Finland | FIN |
| | France | FRA |
| | United Kingdom | GBR |
| | Greece | GRC |
| | Ireland | IRL |
| | Italy | ITA |
| | Luxembourg | LUX |
| | Netherlands | NLD |
| | Portugal | PRT |
| | Sweden | SWE |
| Rest of the Americas | Argentina | ARG |
| | Bolivia | BOL |
| | Brazil | BRA |
| | Chile | CHL |
| | Colombia | COL |
| | Costa Rica | CRI |
| | Ecuador | ECU |
| | Guatemala | GTM |
| | Mexico | MEX |
| | Nicaragua | NIC |
| | Panama | PAN |
| | Peru | PER |
| | Paraguay | PRY |
| | Uruguay | URY |
| | Venezuela | VEN |
| | Belize | XCA |
| | Honduras | |
| | El Salvador | |
| | Aruba | XCB |
| | Anguilla | |
| | Netherlands Antilles | |
| | Antigua and Barbuda | |
| | Bahamas | |
| | Barbados | |
| | Cuba | |
| | Cayman Islands | |
| | Dominica | |
| | Dominican Republic | |
| | Guadeloupe | |
| | Grenada | |
| | Haiti | |
| | Jamaica | |
| | Saint Kitts and Nevis | |
| Saint Lucia | | |
| Montserrat | | |
| Martinique | | |
| Puerto Rico | | |

Table B.1 Model regions, Global Trade Analysis Project (GTAP) region codes, and country name concordance *(continued)*

| Model regions | Country name | GTAP region code |
|-------------------------------|-----------------------------------|------------------|
| | Turks and Caicos | |
| | Trinidad and Tobago | |
| | Saint Vincent and the Grenadines | |
| | Virgin Islands, British | |
| | Virgin Islands, US | |
| | Bermuda | XNA |
| | Greenland | |
| | Saint Pierre and Miquelon | |
| | Falkland Islands (Malvinas) | XSM |
| | French Guiana | |
| | Guyana | |
| | Suriname | |
| Rest of high-income countries | Canada | CAN |
| | Switzerland | CHE |
| | Norway | NOR |
| | Iceland | XEF |
| | Liechtenstein | |
| Rest of the world | Albania | ALB |
| | Armenia | ARM |
| | Azerbaijan | AZE |
| | Belarus | BLR |
| | Botswana | BWA |
| | Egypt | EGY |
| | Ethiopia | ETH |
| | Georgia | GEO |
| | Croatia | HRV |
| | Iran, Islamic Republic of | IRN |
| | Kazakhstan | KAZ |
| | Kyrgyzstan | KGZ |
| | Morocco | MAR |
| | Madagascar | MDG |
| | Mozambique | MOZ |
| | Mauritius | MUS |
| | Malawi | MWI |
| | Nigeria | NGA |
| | Russian Federation | RUS |
| | Senegal | SEN |
| | Tunisia | TUN |
| | Turkey | TUR |
| | Tanzania, United Republic of | TZA |
| | Uganda | UGA |
| | Ukraine | UKR |
| | Angola | XAC |
| | Congo, Democratic Republic of the | |
| | Central African Republic | XCF |
| | Cameroon | |
| | Congo | |

(continued on next page)

Table B.1 Model regions, Global Trade Analysis Project (GTAP) region codes, and country name concordance *(continued)*

| Model regions | Country name | GTAP region code |
|---------------|--|------------------|
| | Gabon | |
| | Equatorial Guinea | |
| | São Tomé and Príncipe | |
| | Chad | |
| | Burundi | XEC |
| | Comoros | |
| | Djibouti | |
| | Eritrea | |
| | Kenya | |
| | Mayotte | |
| | Reunion | |
| | Rwanda | |
| | Sudan | |
| | Somalia | |
| | Seychelles | |
| | Moldova, Republic of | XEE |
| | Andorra | XER |
| | Bosnia and Herzegovina | |
| | Faroe Islands | |
| | Gibraltar | |
| | Monaco | |
| | Macedonia, Former Yugoslav Republic of | |
| | Serbia and Montenegro | |
| | San Marino | |
| | Algeria | XNF |
| | Libyan Arab Jamahiriya | |
| | American Samoa | XOC |
| | Cook Islands | |
| | Fiji | |
| | Guam | |
| | Kiribati | |
| | Marshall Islands | |
| | Micronesia, Federated States of | |
| | Northern Mariana Islands | |
| | New Caledonia | |
| | Norfolk Island | |
| | Niue | |
| | Nauru | |
| | Palau | |
| | Papua New Guinea | |
| | French Polynesia | |
| | Solomon Islands | |
| | Tokelau | |
| | Tonga | |
| | Tuvalu | |
| | Vanuatu | |
| | Wallis and Futuna | |

Table B.1 Model regions, Global Trade Analysis Project (GTAP) region codes, and country name concordance *(continued)*

| Model regions | Country name | GTAP region code |
|---------------|--------------------------------|---------------------|
| | Samoa | |
| | Lesotho | XSC |
| | Namibia | |
| | Swaziland | |
| | Tajikistan | XSU |
| | Turkmenistan | |
| | Uzbekistan | |
| | Benin | XWF |
| | Burkina Faso | |
| | Côte d'Ivoire | |
| | Cape Verde | |
| | Ghana | |
| | Guinea | |
| | Gambia | |
| | Guinea-Bissau | |
| | Liberia | |
| | Mali | |
| | Mauritania | |
| | Niger | |
| | Saint Helena | |
| | Sierra Leone | |
| | Togo | |
| | United Arab Emirates | XWS |
| | Bahrain | |
| | Iraq | |
| | Israel | |
| | Jordan | |
| | Kuwait | |
| | Lebanon | |
| | Oman | |
| | Palestinian Territory Occupied | |
| | Qatar | |
| | Saudi Arabia | |
| | Syrian Arab Republic | |
| | Yemen | |
| | South Africa | ZAF |
| | Zambia | ZMB |
| | Zimbabwe | ZWE |

Table B.2 Model sectors, GTAP sectors, and ISIC/CPC concordance

| Model sectors | GTAP sectors | ISIC revision 3/CPC code |
|-----------------------------|--|--|
| Rice | 1. Paddy rice 18. Processed rice | 0113, 0114 |
| Other grains | 2. Wheat 3. Cereal, grains nec | 0111, 0112, 0115, 0116, 0119 |
| Vegetables and fruits | 4. Vegetables, fruit, nuts | 012, 013 |
| Nongrain crops | 5. Oil seeds 6. Sugarcane, sugarbeet 7. Plant-based fibers 8. Crops nec | 014, 018, 0192, 015, 016, 017, 0191, 193, 0194, 0199 |
| Livestock | 9. Bovine cattle, sheep, and goats, horses 10. Animal products nec 11. Raw milk 12. Wool, silk-worm cocoons | 0211, 0299, 0212, 0292, 0293, 0294, 0295, 0297, 0298, 0291, 0296 |
| Meat and dairy products | 19. Bovine meat products 20. Meat products nec | 21111, 21112, 21115, 21116, 21117, 21118, 21119, 2161, 21113, 21114, 2112, 2113, 2114, 2162 |
| Sugar | 24. Sugar | 235 |
| Other processed food | 21. Vegetable oils and fats 22. Dairy products, 25. Food products nec | 2163, 2164, 2165, 2166, 2167, 2168, 2169, 217, 218, 22, 212 |
| Beverages and tobacco | 26. Beverages and tobacco products | 24, 25 |
| Forest and fishery products | 13. Forestry 14. Fishing | 02 Forestry, logging and related service activities; 015 Hunting, trapping and game propagation including related service activities; 05 Fishing, operation of fish hatcheries and fish farms; service activities incidental to fishing |
| Oil and gas | 16. Oil 17. Gas | 111 Extraction of crude petroleum and natural gas; 112 Service activities incidental to oil and gas extraction excluding surveying |

| | | |
|--|---|---|
| Coal and other minerals | 15. Coal 18. Minerals nec | 101 Mining and agglomeration of hard coal; 102 Mining and agglomeration of lignite; 103 Mining and agglomeration of peat; 12 Mining of uranium and thorium ores; 13 Mining of metal ores; 14 Other mining and quarrying |
| Textiles | 27. Textiles | 17 Manufacture of textiles; 243 Manufacture of man-made fibers |
| Wearing apparel | 28. Wearing apparel | 18 Manufacture of wearing apparel; dressing and dyeing of fur |
| Leather products | 29. Leather products | 19 Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear |
| Manufacturers | 42. Manufactures nec | 36 Manufacturing nec |
| Wood and paper products | 30. Wood products 31. Paper products, publishing | 20 Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials; 361 Manufacture of furniture; 21 Manufacture of paper and paper products; 2211 Publishing of books, brochures, musical books and other publications; 2212 Publishing of newspapers, journals and periodicals; 2219 Other publishing (photos, engravings, postcards, timetables, forms, posters, art reproductions, etc.); 222 Printing and service activities related to printing |
| Petroleum and coal products | 32. Petroleum, coal products | 231 Manufacture of coke oven products; 232 Manufacture of refined petroleum products |
| Chemical, rubber, and plastic products | 33. Chemical, rubber, plastic products | 233 Processing of nuclear fuel; 241 Manufacture of basic chemicals; 242 Manufacture of other chemical products; 25 Manufacture of rubber and plastic products |
| Mineral products | 34. Mineral products nec | 26 Manufacture of other nonmetallic mineral products |

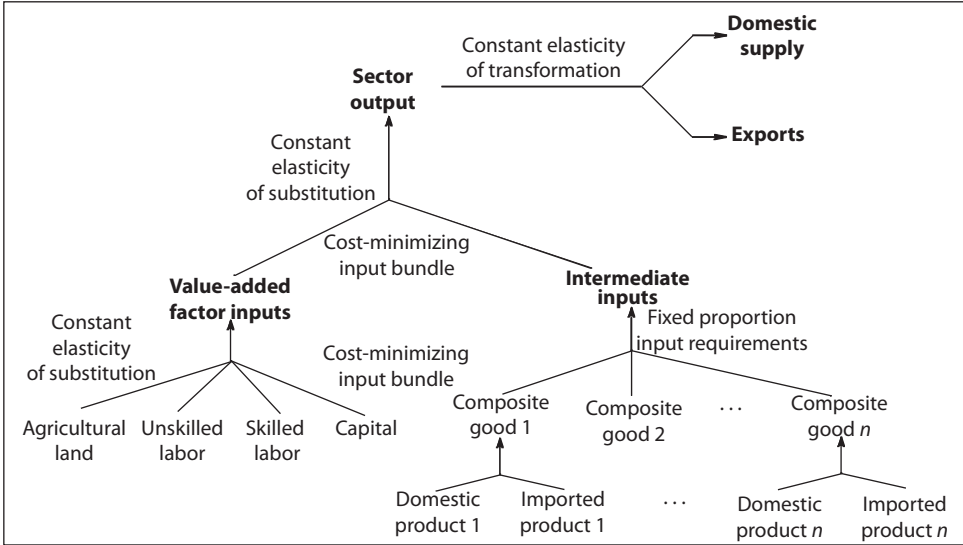
Table B.2 Model sectors, GTAP sectors, and ISIC/CPC concordance *(continued)*

| Model sectors | GTAP sectors | ISIC revision 3/CPC code |
|---------------------------|---|--|
| Metals and metal products | 35. Ferrous metals 36. Metals nec 37. Metal products | 271 Manufacture of basic iron and steel; 2731 Casting of iron and steel; 272 Manufacture of basic precious and nonferrous metals; 2732 Casting of nonferrous metals; 28 Manufacture of fabricated metal products, except machinery and equipment |
| Motor vehicles and parts | 38. Motor vehicles and parts | 34 Manufacture of motor vehicles, trailers and semitrailers |
| Other transport equipment | 39. Transport equipment nec | 35 Manufacture of other transport equipment |
| Electronic equipment | 40. Electronic equipment | 30 Manufacture of office, accounting and computing machinery; 32 Manufacture of radio, television and communication equipment and apparatus |
| Machinery and equipment | 41. Machinery and equipment nec | 2213 Publishing of recorded media; 223 Reproduction of recorded media; 29 Manufacture of machinery and equipment ; 31 Manufacture of electrical machinery and apparatus nec; 33 Manufacture of medical, precision and optical instruments, watches and clocks |
| Trade and transportation | 47. Trade 48. Other transportation 48. Water transportation 49. Air transportation | 521 Nonspecialized retail trade in stores; 522 Retail sale of food, beverages and tobacco in specialized stores; 523 Other retail trade of new goods in specialized stores; 524 Retail sale of secondhand goods in stores; 525 Retail trade not in stores; 60 Land transport; transport via pipelines; 61 Water transport; 62 Air transport; 51 Wholesale trade and commission trade, except of motor vehicles and motorcycles |
| Finance and insurance | 52. Financial services nec 53. Insurance | 65 Financial intermediation, except insurance and pension funding; 66 Insurance and pension funding, except compulsory social security; 67 Activities auxiliary to financial intermediation; |

| | | |
|--|--|--|
| Business services | 54. Business services nec | 70 Real estate activities; 711 Renting of transport equipment; 526 Repair of personal & household goods; 712 Renting of other machinery and equipment; 713 Renting of personal & household goods nec; 72 Computer & related activities; 74 Other business activities |
| Communication | 51. Communication | 64 Post and telecommunications |
| Construction | 46. Construction | 45 Construction |
| Recreational and other services | 55. Recreational and other services | 55 Hotels and restaurants; 63 Supporting and auxiliary transport activities; activities of travel agencies; 92 Recreational, cultural and sporting activities; 93 Other service activities; 95 Private households with employed persons |
| Utilities and other nontradable services | 43. Electricity 44. Gas manufacture, distribution 45. Water 56. Public administration and defense, education, health 57. Dwellings | 401 Production, collection and distribution of electricity; 402 Manufacture of gas; distribution of gaseous fuels through mains; 403 Steam and hot water supply; 41 Collection, purification and distribution of water; 90 Sewage and refuse disposal, sanitation and similar activities; 73 Research and development; 75 Public administration and defense compulsory social security; 80 Education; 85 Health and social work; 91 Activities of membership organizations nec; 99 Extraterritorial organizations and bodies |

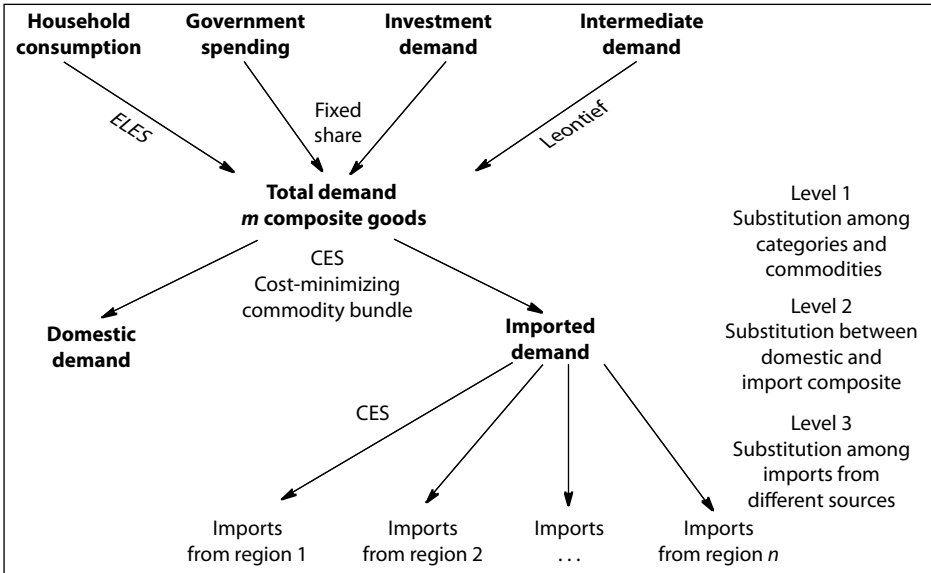
GTAP = Global Trade Analysis Project; ISIC/CPC = International Standard Industrial Classification/Central Product Classification; nec = not elsewhere classified.

Figure B.1 Structure of production



... = additional goods or products

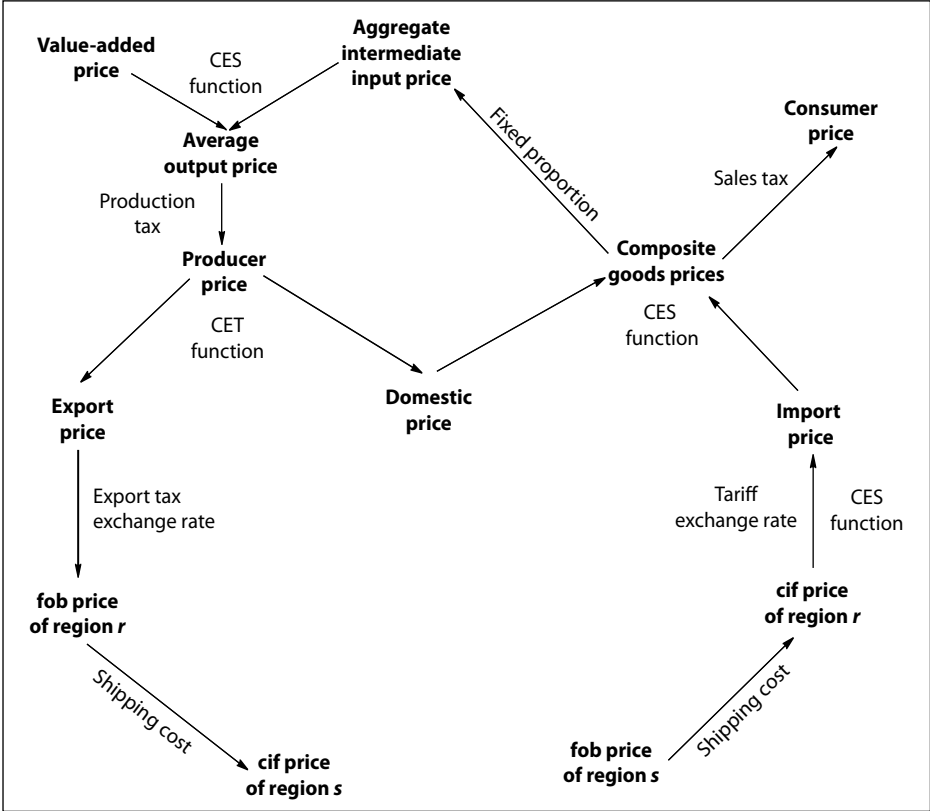
Figure B.2 Structure of demand



... = additional goods or products; CES = constant elasticity of substitutions; ELES = extended linear expenditure system

Note: Leontief refers to Leontief production technology, which assumes no substitution among different intermediate inputs.

Figure B.3 The price system



CES = constant elasticity of substitution; CET = constant elasticity of transformation; cif = cost, insurance, and freight; fob = free on board

Table B.3 Definitions of variables

| Variable | Definition | Number of variables |
|-------------|---|--|
| PWE_{isr} | World fob price for goods from region s to region r | $I \times R(R - 1)$ (12,160) |
| PWM_{isr} | World cif price for goods from region s to region r | $I \times R(R - 1)$ (12,160) |
| PM_{ir} | Price of aggregate imported goods in region r | $I \times R$ (640) |
| PX_{ir} | Price of composite goods in region r | $I \times R$ (640) |
| PD_{ir} | Price of domestic products sold at domestic market in region r | $I \times R$ (640) |
| PE_{ir} | Price of domestic goods for export in region r | $I \times R$ (640) |
| PC_{ir} | Domestic consumer price in region r | $I \times R$ (640) |
| PP_{ir} | Average output price before production tax in region r | $I \times R$ (640) |
| P_{ir} | Average output price after production tax in region r | $I \times R$ (640) |
| PF_{ir} | Factor price in region r | $F \times R$ (120) |
| PV_{ir} | Price of value added in region r | $I \times R$ (640) |
| PN_{ir} | Price of aggregate intermediate inputs in region r | $I \times R$ (640) |
| CPI_r | Price of savings in region r (consumer price index) | R (20) |
| ER_r | Exchange rate of region r | R (20) |
| PID_r | Price index in region r | R (20) |
| Q_{ir} | Sector output in region r | $I \times R$ (640) |
| VA_{ir} | Variable sector production cost in region r | $I \times R$ (640) |
| NX_{ir} | Aggregate sector intermediate input in region r | $I \times R$ (640) |
| DF_{fir} | Sector factor demand in region r | $(F - 3) \times I \times R + (IAG + RES) \times R$ (2,080) |
| DX_{ir} | Sector domestic sales in region r | $I \times R$ (640) |
| EX_{ir} | Domestic goods for export in region r | $I \times R$ (640) |
| C_{ir} | Household consumption in region r | $I \times R$ (640) |
| GC_{ir} | Government spending in region r | $I \times R$ (640) |
| ID_{ir} | Investment demand in region r | $I \times R$ (640) |
| TX_{ir} | Composite goods demand (supply) in region r | $I \times R$ (640) |
| MX_{ir} | Sector composite goods imports in region r | $I \times R$ (640) |
| X_{isr} | Trade flows from region s to region r | $I \times R(R - 1)$ (12,160) |
| TRQ | Total international transportation supply | 1 |
| PTR | Price of international shipping service | 1 |
| $TRQD_{ir}$ | International shipping demand by region r | $I \times R$ (640) |
| $TRQS_r$ | International shipping service supply by region r | R (20) |
| HDI_r | Household disposable income in region r | R (20) |
| SY_r | Household supernumerary income in region r | R (20) |
| GR_r | Total government revenue in region r | R (20) |
| GSP_r | Total government spending in region r | R (20) |
| $TARRIF_r$ | Total tariff revenue in region r | R (20) |
| $ETAX_r$ | Total export tax revenue (subsidy expenditure) in region r | R (20) |
| $PTAX_r$ | Total production tax revenue in region r | R (20) |
| $CTAX_r$ | Total consumer sale tax in region r | R (20) |
| SAV_r | Household saving in region r | R (20) |
| $GSAV_r$ | Government saving (deficit) in region r | R (20) |
| $GTRNS_r$ | Government transfer in region r | R (20) |
| BOT_r | Balance of trade in region r (net capital inflow) | R (20) |
| INV_r | Gross investment by region r | R (20) |
| $ITFP_{ir}$ | Import-embodied total factor productivity shifter by sector in region r | $I \times R$ (640) |
| FS_{fir} | Factor endowment by region r | $F \times R$ (160) |
| | Total number of variables: | $17 \times R + (2 \times F + IAG + RES) \times R + 21 \times I \times R + 3 \times I \times R(R - 1) + (F - 3) \times I \times R + 2$ (52,582) |

fob = free on board; cif = cost, insurance, and freight.

Table B.4 Definitions of parameters

| Parameter | Definition |
|------------------|---|
| te_{isr} | Sector export tax (subsidy) rate for goods to region r from region s |
| tm_{isr} | Sector tariff rate for goods from region s in region r |
| tn_{isr} | Sector nontariff barrier for goods from region s in region r |
| tp_{ir} | Sector indirect tax rate in region r |
| tc_{ir} | Consumer sales tax rate in region r |
| trc_{isr} | International transportation cost margin as percent value of fob |
| io_{ijr} | Input/output coefficients for region r |
| kio_{ir} | Sector share of total investment in region r |
| dk_r | Depreciation rate of capital stock in region r |
| τ_r | Regional share of international shipping service supply |
| Γ_{ir} | Unit coefficients in first-level Armington aggregation function |
| μ_{ir} | Unit coefficients in second-level Armington aggregation function of region r |
| α_{ir} | Share parameters in the first-level Armington aggregation function of region r |
| ξ_{ir} | Share parameters in the second-level Armington aggregation function of region r |
| σm_i | Substitution elasticities between domestic and import goods |
| σt_i | Substitution elasticities among import goods from different regions |
| χ_{ir} | Unit coefficients in CET function of region r |
| κ_{ir} | Share parameters in CET function of region r |
| σe_i | Elasticities of transformation between domestic sales and exports |
| A_{ir} | Unit parameter in aggregate cost function |
| λ_{ir} | Intermediate input share in aggregate cost function |
| σp_{ir} | Elasticities of substitution between aggregate factor and intermediate input |
| Λ_{ir} | Unit parameter in value-added function |
| δ_{fir} | Factor share in value-added function |
| σv_{ir} | Elasticities of substitution among primary factors in value added |
| γ_{ir} | Sector minimum subsistence requirements for private households in region r |
| β_{ir} | Marginal propensity to consume for private households in region r |
| Mps_r | Marginal propensity to save for private households in region r |
| θ_r | Sector share of government spending in region r |
| Tfp_r | General total factor productivity shifter in region r |
| lms_{ir} | Share of intermediate inputs in sector's total imports |
| σip_{ir} | Elasticity between intermediate goods import growth with total factor productivity growth |
| dl_r | Land depletion rate in region r |
| Ds_r | Share of additional tertiary education stock that goes to skilled labor force at each period |
| $t\varphi_r$ | Parameter that controls the speed of wage convergence between agriculture and unskilled labor |
| N_{rt} | Population growth rate in region r at period t |
| Wdf_r | Wage ratio of agricultural labor and unskilled labor in region r at base year |

fob = free on board; CET = constant elasticity of transformation.

