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An Application of the Computable General Equilibrium Model to Analyze U.S. Ariculture

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Disciplines
Agricultural and Resource Economics | Agricultural Economics | Econometrics | Macroeconomics

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Introduction

The importance to the agricultural sector of exchange rates and other instruments of monetary and fiscal policies was first emphasized by Schuh (1974). His seminal work sparked other studies of the interaction between agricultural production and incomes and traditional instruments of macroeconomic policy. Integrated sectorial and macroeconomic models to study the impact of interest and exchange rates on U.S. agriculture have been formulated by Shei (1978), Hughes and Penson (1980), and Chambers and Just (1982). These studies are mostly empirical and are not "complete" general equilibrium models. They fail to recognize the full circular flow of income and goods in the economy.

This study presents a computable general equilibrium (CGE) model for the U.S. economy with emphasis on the agricultural sector. The model is in the tradition of Walrasian price endogenous models, generating equilibrium solutions for both quantities and prices. The model is based on a social accounting matrix (SAM) information system. The model is static and is calibrated for the base year 1982. The estimated model is then used to carry out two counterfactual experiments to analyze the impact of exchange rate and capital stock shocks on agriculture.

A SAM for the United States

As a data framework the SAM provides a "snapshot" of the economy and describes the full circular flow of money and goods. In the SAM, the rows and columns represent the receipt and expenditure accounts, of economic actors. Thus, the SAM is a square matrix whose row and column sums must balance. Such a SAM is constructed for the United States for the year 1982 (Table 1) by modifying national income and product accounts data and using other relevant data and information. For a discussion on the construction of a SAM, see Pyatt and Round

Table 1. SAM for the United States, 1982

Account	Activities			Factors		Institutions				
	Agri. 1	Agri. Related 2	Other 3	Labor Income 4	Capital Income 5	Enter-prises 6	Households 7	Capital Account 8	Govt. 9	Rest of World 10
						billion $				
Activities										
Agriculture	49.91	93.81	9.81				20.42	-0.22	8.28	19.41
Ag. related act.	70.63	1119.77	442.84				1714.43	40.55	451.88	97.33
Other activities	7.97	452.87	644.77				250.04	374.53	190.32	231.68
Factors										
Labor income	18.79	1314.26	531.17							
Capital income	45.13	701.08	200.06							
Institutions										
Enterprises					834.77				53.25	
Households				1612.96	111.51	439.30			361.92	-1.17
Capital account						388.05	135.50		-115.24	6.55
Government	3.64	217.21	37.92	251.31		60.66	404.08		179.51	-24.42
Rest of the world	5.35	38.42	285.63							
Totals	201.43	3937.42	2152.19	1864.22	946.27	888.01	2120.39	414.86	1129.91	329.40

Note: This SAM is, in principle, the same as the one constructed by Adelman and Robinson (1986). The agricultural related sector in the SAM includes food processing, wholesale retail trade, utilities, banking, chemicals, and services.

(1985). Table 1 reveals that about 75 percent of total agricultural expenditures are for purchases of nonagricultural inputs. The table suggests that there are significant linkages between the agricultural sector and the rest of the economy.

Assumptions and Structure of the Model

Closure Rule 1

Closure Rule 1 has three production sectors, an agricultural sector, an agricultural related sector, and an aggregate "other" production sector. Other endogenous accounts include two primary factors, labor and capital, plus a household sector, an investment sector, a government sector, and a rest of the world sector. See Appendices A and B for a complete list of equations and variable definitions.

Production in each sector is described by a two-level, fixed coefficient, value-added production system:

$$X_i = \min\{V_i/a_{vi},\ X_{ij}/a_{ij}\ \ j = 1,2,3\} \qquad i = 1,2,3 \qquad (1)$$

where X_i is the gross output of industry i; V_i is the value added in industry i; a_{vi} is the value added requirement per unit of output i; X_{ij} is the use of good j in industry i, and a_{ij} is the requirement of good j per unit of good i. Substitution between the primary factors of labor and capital is allowed in meeting each industry's value-added requirements through the CES function

$$V_i = b_i[d_i L_i^{1-1/\sigma_i} + (1 - d_i)K_i^{1-1/\sigma_i}]^{\sigma_i/(\sigma_i - 1)} \qquad i = 1,2,3 \qquad (2)$$

where L_i is the amount of labor used in industry i; K_i is the amount of capital used in industry i; and b_i, d_i, and σ_i are parameters. Indirect taxes are levied as a fixed proportion of gross revenue. Profit maximization is assumed in all three production sectors and input demand functions are derived accordingly. The economy has fixed amounts of resources and full use of these factors is assumed. Since factor prices are the same across all sectors, it is ensured that the marginal value product of a factor is the same in all sectors.

Labor income is transferred to households, the owners of factors, after paying a fixed percentage of factor tax. Capital income is transferred to households and enterprises. A portion of enterprises income is invested. After paying a constant proportion of capital income tax, the rest is distributed among households. Labor income, capital income, and enterprise income, together with some government transfer minus net remittances to the rest of the world, form the total gross income of households. Households have a fixed rate of savings and income tax. Disposable income for households is obtained by subtracting the savings and income tax from their gross income. Households maximize their utility subject to this level of disposable income. The total household consumption expenditure is allocated to the three goods as a linear expenditure system.

Government revenue consists of indirect business taxes, factor taxes, corporate taxes and net foreign reserve accumulations. Government expenditures include final consumption expenditures on the three goods, plus transfers to households and corporations. The government budget surplus is endogenously determined as the difference between government revenues and expenditures. Savings come from households, enterprises, foreign capital inflow, and government and equal total investment in the economy. Investments are divided into three sectors based on endogenously determined shares.

To determine exports and imports, simple export demand and import supply functions are used under this closure rule. It is assumed that world export demands and import supplies depend only on own prices and are of the constant elasticity form:

$$E_i = e_i (P_i/\bar{x})^{\eta_i} \qquad i = 1,2,3 \quad -\infty < \eta \le 0 \qquad (3)$$

$$M_i = m_i \{P_i(1 - \bar{t}_i)/\bar{x}\}^{\tau_i} \qquad i = 1,2,3 \quad \infty > \tau_i \ge \qquad (4)$$

where E_i is exports of good i; M_i is imports of good i; P_i is domestic price of good i; $\bar{x}$ is the exchange rate; and t_i is the tariff rate. Therefore, $P_i/\bar{x}$ and $p_i(1 - t_i)/\bar{x}$ are the world prices of exports and imports respectively. Further, η_i and γ_i are restricted to be finite since infinite elasticities would exogenously fix domestic prices. Thus, the economy considered here cannot technically be a "small open" one.

Balance of trade is endogenously determined as the difference between value of exports and imports. Finally, system constraints are imposed so that supply equals demand in each market. Thus, the excess demand functions in each market are set to equal zero and are solved for prices. Since the model is Walrasian, only relative prices matter. The price of agricultural related goods is taken as the numéraire.

Alternative Closure Rule

The model is not completely satisfactory for several reasons. In the data, 1982 SAM for the United States, all three products are both exported and imported at the same time. But the specification in (4) treats imports of a product as a perfect substitute for a domestically produced product. At the same time, the world price of exports of product i ($P_i/\bar{x}$) may differ from the world price of imports $P_i(1 - t_i)/\bar{x}$ because of tariffs. Therefore, the perfect substitutability between domestically produced products and imported products is assumed to hold in the United States cannot hold abroad. In other words, cross-hauling of the products is not explained adequately because of the aggregate nature of the industry data that is used. To overcome this problem, an alternate closure rule is examined in which imports are treated as imperfect substitutes for domestic products. Imports are substitutable for domestic products in both final demand and intermediate use. The representation of the substitutability is achieved by defining a new commodity (Q_i), which is a composite of domestically produced goods (X_i) and imports (M_i) where the composite is a CES-type function. This is the Armington approach, where goods of both foreign and domestic origin are brought together to form a composite bundle that is used to meet domestic demand. Imports are specified as derived demand and take the form:

$$M_i = m_i \{P_i^c / (\bar{P}_i \bar{x}(1 + t_i))\}^{\mu_i} Q_i \qquad (5)$$

where P_i^c is the price of composite good i; $\bar{P}_i$ is the world price of good i, and assumed to be fixed; μ_i is the elasticity of substitution between domestically produced goods and imported goods in Sector i; and m_i is a scaling parameter. The United States is a small open economy in import markets, though not in export markets. The other equations in this closure rule are the same as in the earlier case except that demanders of goods now pay the composite good price rather than domestic (producer) price. Also, the price of composite goods is determined so that the demand for the composite good equals the supply. Throughout the rest of this discussion this treatment of imports is referred to as closure rule 2.

Calibration and Parameter Estimation

The calibration procedure outlined in Mansur and Whalley (1984) has been followed to estimate the parameter values. However, a few of the model's parameters cannot be estimated from the base year SAM listed in Table 1. These are elasticities of factor substitution (σ_i), price elasticities of exports (η_i), price elasticity of imports (γ_i) (for closure rule 1), and elasticity of substitution between imports and domestically produced goods (μ_i)(for closure rule 2). These parameters are exogenously specified (see Table 2) based on previous empirical literature (Berndt 1973, Ray 1982, Meyers 1986, Gardiner 1987). Alternatively, all the parameters can, in principle, be estimated simultaneously if suitable time series data are available. The gain in efficiency may or may not be worth the extra effort involved. The model is calibrated separately under the two closure rules to exactly

Table 2. Exogenously specified elasticities in the model

Elasticity	Value
Elasticity of factor substitution	
Agriculture sector (σ_1)	0.50
Ag. related sector (σ_2)	0.50
Other sector (σ_3)	0.50
Price elasticity of exports	
Agriculture sector (η_1)	-0.30,-0.50,-0.80
Ag. related sector (η_2)	-0.30
Other sector (η_3)	-0.30
<u>Closure rule 1:</u>	
Price elasticity of imports	
Agriculture sector (γ_1)	0.50
Ag. related sector (γ_2)	0.50
Other sector (γ_3)	0.50
<u>Closure rule 2:</u>	
Elasticity of substitution between imports and domestic goods (in the closure rule 2)	
Agriculture sector (μ_1)	2.00
Ag. related sector (μ_2)	2.00
Other sector (μ_3)	2.00

reproduce the base case as set out in the initial SAM. This guarantees that at least in one case the model has a solution. Counterfactual equilibrium situations can be compared to this base.

Since some parameters are specified exogenously, the sensitivity of endogenous variables to changes in these parameters is examined. Values of exogenously imposed parameters are changed, one at a time, and changes in the endogenous variables are computed. In a total of more than 50 such cases, more than four-fifths of elasticities of endogenous variables to exogenously specified parameters were less than 0.1 in absolute value. The results obtained with this model can thus be considered robust to large changes in the exogenous parameters.

Results

Results are reported on the impact of changes in the value of the U.S. dollar and the capital stock on U.S. agriculture and the economy in general. The experiments we chose are a 10 percent decrease in U.S. dollar value and a 10 percent increase in capital stock. In both these experiments the model is solved for quantities and prices after exogenously injecting the shock. The analysis is carried out under both closure rules 1 and 2, enabling us to examine the sensitivity of results to the specifications of the closure rules. Results under some parameter changes to which endogenous variables are sensitive are also presented.

Results of the two experiments under closure rule 1 are summarized in Table 3. Table 4 presents the results of the same experiments under closure rule 2. There are more than one hundred endogenous variables in the model, so discussion is limited to the more interesting variables.

The results presented in Table 3 indicate, as expected, that a devaluation of the U.S. dollar increases exports and decreases imports in all three sectors. Consequently, the balance of trade improves considerably. Balance of trade is more sensitive to exchange rate fluctuations than quantity

Table 3. Results of the experiments under closure rule 1

Variable	1982 Value in 1982 Bil. dollars	Experiment 1. 10% Decrease in U.S. $ Value. % Change from base η_1=-0.30	η_1=-0.50	η_1=-0.80	Experiment 2. 10% Increase in Capital Stock % Change from base η_1=-0.50
Production:					
Agriculture	196.07	0.14	0.26	0.64	3.94
Ag. related	3899.01	-0.54	-0.55	-0.56	4.47
Other	1866.55	1.48	1.49	1.49	-0.49
Exports:					
Agriculture	19.41	2.86	4.82	7.83	-4.65
Ag. related	97.33	2.85	2.85	2.86	-3.67
Other	231.68	2.85	2.85	2.85	-3.90
Imports:					
Agriculture	5.35	-4.59	-4.60	-4.60	4.88
Ag. related	38.43	-4.57	-4.58	-4.59	6.43
Other	285.63	-4.57	-4.57	-4.58	6.85
Labor Use:					
Agriculture	18.79	-0.08	0.18	0.78	-2.63
Ag. related	1314.26	-0.58	-0.59	-0.60	1.22
Other	531.17	1.44	1.45	1.46	-2.92
Capital Use:					
Agriculture	45.13	0.05	0.30	0.68	6.94
Ag. related	701.08	-0.45	-0.47	-0.49	11.16
Other	200.06	1.58	1.58	1.57	6.61
Capital Labor Ratio:					
Agriculture	2.40	0.13	0.12	0.11	9.83
Ag. related	0.53	0.13	0.12	0.11	9.83
Other	0.38	0.13	0.12	0.11	9.83
Money Metric	1984.89	-0.61	-0.62	-0.64	5.06
Balance of trade	19.02	131.60	133.74	137.04	-206.20
GNP	3069.25	0.15	0.14	0.12	17.09
Prices (1982=1.00)					
Agriculture	1.00	-0.04	-0.04	-0.04	-2.89
Other	1.00	0.01	0.01	0.01	0.79
Labor	1.00	0.09	0.08	0.07	6.48
Capital	1.00	-0.17	-0.16	-0.14	-11.72

Notes: η_1 is the price elasticity of agricultural exports. All prices are relative prices, relative to the price of agricultural related good. GNP and Balance of trade are measured in current dollars. All other variables are measured in 1982 dollars.

Table 4. Results of the experiments under closure rule 2

Variable	1982 Value in 1982 Bil. dollars	Experiment 1. 10% Decrease in U.S. $ Value. % Change from base η_1=-0.30	η_1=-0.50	η_1=-0.60	Experiment 2. 10% Increase in Capital Stock % Change from base η_1=-0.50
Production:					
Agriculture	196.07	0.37	0.61	0.98	3.55
Ag. related	3899.01	-0.60	-0.61	-0.62	4.70
Other	1866.55	2.96	2.97	2.98	-3.02
Exports:					
Agriculture	19.41	2.77	4.67	7.59	-4.43
Ag. related	97.33	2.76	2.76	2.76	-3.52
Other	231.68	2.79	2.80	2.80	-3.81
Imports:					
Agriculture	5.35	-16.59	-16.55	-16.50	25.16
Ag. related	38.43	-17.14	-17.17	-17.21	33.25
Other	285.63	-14.29	-14.31	-14.33	25.82
Labor Use:					
Agriculture	18.79	0.06	0.31	0.68	-2.73
Ag. related	1314.26	-0.70	-0.70	-0.71	1.54
Other	531.17	1.72	1.72	1.74	-3.70
Capital Use:					
Agriculture	45.13	0.21	0.45	0.81	6.76
Ag. related	701.08	-0.55	-0.56	-0.59	11.44
Other	200.06	1.87	1.87	1.87	5.69
Capital Labor Ratio:					
Agriculture	2.40	0.15	0.14	0.13	9.75
Ag. related	0.53	0.15	0.14	0.13	9.75
Other	0.38	0.15	0.14	0.13	9.75
Money Metric	1984.89	-1.00	-1.01	-1.03	5.82
Balance of trade	19.02	164.40	166.48	169.67	-297.00
GNP	3069.25	0.21	0.20	0.19	16.93
Prices (1982=1.00)					
Agriculture	1.00	-0.06	-0.06	-0.06	-2.86
Other	1.00	-0.12	-0.12	-0.13	1.01
Labor	1.00	-0.17	-0.18	-0.19	6.88
Capital	1.00	-0.47	-0.46	-0.45	-12.70
Prices-Composite Good:					
Agriculture	1.00	0.20	0.20	0.20	-3.13
Ag. related	1.00	0.09	0.09	0.09	-0.13
Other	1.00	1.20	1.20	1.20	-1.03

Notes: η_1 is the price elasticity of agricultural exports. All prices are relative prices, relative to the price of agricultural related good. GNP and Balance of trade are measured in current dollars. All other variables are measured in 1982 dollars.

changes because of a price effect enforcing the quantity changes. On the production side, the agriculture sector as well as the other sectors expand, whereas output of the agricultural related total labor and total capital in the economy are fixed, at least one sector has to contract when another expands. The agricultural sector expands to benefit from a devaluation of the U.S. dollar. Wage rate rises relative to the price of capital and all sectors become more capital intensive. It may be noted here that the capital labor ratio rises in all sectors by the same percentage points. This is because, by assumption, the elasticity of substitution between capital and labor is the same in all three sectors. GNP of the economy goes up slightly.

However, on the demand side, consumers are hurt because of an increase in the general price level and a decrease in personal income. This is evident by a decrease in the money-metric.[2] Personal income goes down because the trade surplus increases more than does value added after taxes; i.e., the economy is saving more money (to be lent abroad) instead of making it available for current domestic consumption. The benefits from this savings cannot be measured in a static model like this one.

The results seem to be qualitatively invariant to changes in the export demand elasticity. However, some endogenous variables such as exports, imports, and balance of trade seem to be more sensitive to exchange rate fluctuations when export elasticities are larger in absolute value.

Qualitatively, results are quite similar under closure rule 2 (see Table 4) except that variables are more sensitive. The higher responsiveness of trade variables can be attributed to the fact that closure rule 2 leads to adjustment in the composition of consumption goods. Because of a decrease in world prices relative to domestic prices, the share of imports in composite goods increases. Adjustments in production to exchange rate changes are stronger under closure rule 2 than under closure rule 1. Prices are also considerably more sensitive under closure rule 2. Agricultural prices increase relative to the other sector but still decline in comparison to the agricultural related sector. These results are different from those under closure rule 1 and may be attributed to the changes in consumer preference toward cheaper imports. In general, results are consistent with results in exchange rate literature (Shei 1978).

When the total capital stock in the economy is increased, relatively capital intensive agriculture and agriculture related sectors benefit. Production in both these sectors increases, whereas the production of the other sector decreases. As expected, all sectors become more capital intensive because of cheaper capital. Because of increased factor supply, personal income increases, leading to a higher demand for imported goods. As a result, imports increase and balance of trade worsens. As in the previous experiment, the results are qualitatively similar under both closures.

Summary

A simple computable general equilibrium model based on a social accounting matrix has been presented. The model is developed on the basis of theoretically plausible specifications, incorporating a wide range of interaction effects. The model allows for substitution possibilities in production and consumption and is capable of addressing a wide array of policy questions. The model is calibrated to 1982 data under two different specifications of closure rules. Two policy experiments are carried out by shocking the exchange rate and capital stock. Results indicate that there are significant linkages between the agricultural sector and the rest of the economy. Specifically, a devaluation of the U.S. dollar seems to have a positive effect on the agricultural sector and balance of trade while hurting consumers. This and other general qualitative results are found to be robust under differing assumptions about elasticities of world demand for exports. When the capital stock is increased, more capital-intensive agriculture and agriculture related sectors benefit the most.

A number of refinements can easily be made in the model. An obvious extension would be to incorporate a higher degree of sectorial disaggregation and to introduce dynamics. Dynamics is especially important because some policy changes take more than one period to impact fully on the economy. Labor may also be divided into skilled and unskilled, the factor supply can be endogenized, and the full employment assumption can be relaxed. A more interesting extension would be to introduce uncertainty.

Appendix A
Closure Rule 1 Equations and Variables

Included here are the model equations and variable definitions under closure rule 1. A bar on a variable indicates that it is exogenous. Lowercase letters are parameters that can be estimated from the base year SAM. Greek letters indicate exogenously specified parameters. In general, i and j subscripts refer to production sectors and h subscript refers to households. Superscripts i and e refer to income and expenditure.

Production and Factor Use

(A.1) $X_{ij} = a_{ij}X_j$ $\quad i = 1,2,3 \quad j = 1,2,3$

(A.2) $V_i = a_{vi}X_i$ $\quad i = 1,2,3$

(A.3) $L_i = l_i(P_i/w)^{\sigma_i}X_i$ $\quad i = 1,2,3$

(A.4) $K_i = k_i(P_i/r)^{\sigma_i}X_i$ $\quad i = 1,2,3$

(A.5) $T_{ib} = t_{ib} \cdot P_iX_i$ $\quad i = 1,2,3$

(A.6) $\sum_{j=1}^{3} P_iX_{ji} + wL_i + rK_i + T_{ib} = P_iX_i$ $\quad i = 1,2,3$

(A.7) $\sum_{i=1}^{3} K_i = \bar{K}$

(A.8) $\sum_{i=1}^{3} L_i = \bar{L}$

Income and Investment

(A.9) $L_y = \sum_{i=1}^{3} w\, L_i$

(A.10) $T_\ell = t_\ell\, L_y$

(A.11) $L_{hy} = \ell_h L_y$

(A.12) $T_\ell + L_{hy} = L_y$

(A.13) $K_y = \sum_{i=1} r K_i$

(A.14) $K_{ey} = k_e \cdot K_y$

(A.15) $K_{hy} = k_h \cdot K_y$

(A.16) $K_{ey} + K_{hy} = K_y$

(A.17) $N^i = K_{ey} + G_e$

(A.18) $N_h = n_h N^e$

(A.19) $T_c = t_c N^e$

(A.20) $N_s = n_s N^e$

(A.21) $N_h + T_c + N_s = N^e$

(A.22) $N^i = N^e$

(A.23) $S = N_s + S_h + G_s + R_s$

(A.24) $I_i = i_i I$ $\quad i = 1,2,3$

(A.25) $I = \sum_{i=1}^{3} I_i$

(A.26) $S = I$

Household Income and Consumption

(A.27) $Y_h^i = L_{hy} + K_{hy} + G_h - R_h$

(A.28) $T_h = t_h \cdot Y_h^e$

(A.29) $S_h = s(Y_h^e - T_h)$

(A.30) $C_{ih} = c_{ih} \cdot (Y_h^e - T_h - S_h)/P_i$ $\quad i = 1,2,3$

(A.31) $$Y_h^e = T_h + S_h + \sum_{i=1}^{3} P_i C_{ih}$$

(A.32) $$Y_h^e = Y_h^i$$

Government Revenue and Expenses

(A.33) $$G^i = \sum_{i=1}^{3} T_{ib} + T_\ell + T_c + T_h + R_g$$

(A.34) $$C_{ig} = c_{ig} \; G^e/P_i \qquad i = 1,2,3$$

(A.35) $$G_e = g_e \; G^e$$

(A.36) $$G_h = g_h \; G^e$$

(A.37) $$G^e = \sum_{i=1}^{3} C_{ig} + G_e + G_h$$

(A.38) $$G_s = G^i - G^e$$

Foreign Trade

(A.39) $$M_i = m_i \; P_i^{\gamma_i} \; \bar{x}^{-\gamma_i} \quad \gamma_i > 0 \qquad i = 1,2,3$$

(A.40) $$E_i = e_i \; P_i^{\eta_i} \bar{x}^{-\eta_i} \quad \eta_i < 0 \qquad i = 1,2,3$$

(A.41) $$R_h = r_h \; R$$

(A.42) $$R_s = r_s \; R$$

(A.43) $$R_g - r_g \; R$$

(A.44) $$R = \sum_{i=1}^{3} P_i E_i - R_h + R_s + R_g$$

(A.45) $$P_i X_i = \sum_{j=i}^{3} P_i X_{ij} + P_i C_{ih} + I_i + P_i C_{ig} + P_i E_i - P_i M_i i =$$

(A.46) $$B = \sum_{i=1}^{3} P_i E_i - \sum_{i=1}^{3} \{P_i \; (1-t_i)/\bar{x}_i\} \; M_i$$

Endogenous Variables

B	Balance of trade
C_{ig}	Government final consumption demand for good i
C_{ih}	Household consumption demand for good i
E_i	Exports of good i
G_e	Government transfers to enterprises
G_h	Government transfers to households
G_s	Government surplus
G^e	Total government expenses
G^i	Total government revenue
I	Total investment
I_i	Investment in the i^{th} sector
K_i	Capital used in the i^{th} sector
K_{ey}	Capital income accrued to enterprises
K_{hy}	Capital income accrued to households
K_y	Total capital income
L_i	Labor used in the i^{th} sector
L_{hy}	Labor income accrued to households
L_y	Total labor income
M_i	Imports of i^{th} good
N_h	Corporate profits distributed to households
N_s	Retained (saved) corporate profits
N^e	Total enterprise expenditure
N^i	Total enterprise income
P_i	Domestic price of good i
r	Price of capital
R	Total foreign exchange accumulation
R_g	Total government reserve decumalation
R_h	Net foreign remittances of household
R_s	Net capital inflow from the rest of the world
S	Total savings of the economy
S_h	Saving of households

T_c	Corporate taxes
T_{ib}	Indirected business tablespaid by i^{th} sector
T_h	Income tax paid by households
T_ℓ	Factor taxes paid by labor sector
V_i	Value added by sector i
w	Wage rate
X_i	Total gross output of sector i
X_{ij}	Amount of good i used in the sector j
Y_h^e	Total expenditure of households
Y_h^i	Total income of households

Exogenous Variables

$\bar{K}$	Total capital stock in the economy
$\bar{L}$	Total labor hours available in the economy
$\bar{x}$	Exchange rate, $/SDR

Appendix B
Closure Rule 2 Equations and Variables

Equations for the model under closure rule 2 that differ from that in closure rule 1 (Appendix A) are presented here. The model under closure rule 2 has equations (A.1)-(A.5), (B.6), (A.7)-(A.29), (B.30), (B.31), (A.32), (A.33), (B.34), (A.35)-(A.38), (B.39), (A.40)-(A.44), (B.45), (A.46), (B.47), and (B.48).

(B.6) $\sum_{j=1}^{3} P_i^c X_{ji} + wL_i + rK_i + T_{ib} = P_i X_i$ $\quad i = 1,2,3$

(B.30) $C_{in} = c_{ih}(Y_n^e - T_n - S_h)/P_i^c$ $\quad i = 1$

(B.31) $Y_h^e = T_h + S_h + \sum_{i=1}^{3} P_i^c C_{ih}$

(B.34) $C_{iq} = C_{ig} \cdot G^e/P_i^c$ $\quad i = 1,2,3$

(B.39) $M_i = m_i\{P_i^c/[\bar{P}_i\bar{x}(1 + t_i)]\}^{\mu_i} Q_i \quad \mu_i > 0$ $\quad i = 1,2,3$

(B.45) $X_i = D_i + E_i$ $\quad i = 1,2,3$

(B.47) $D_i = (1 - m_i)\{P_i^c/P_i\}^{\mu_i} Q_i \quad \mu_i > 0$ $\quad i = 1,2,3$

(B.48) $P_i^c Q_i = P_i D_i + \{\bar{P}_i\bar{x}(1 + t_i)\}M_i$

Endogenous Variables

PD_i	Domestic supply for the final demanded
P_i^c	Price of i^{th} composite good
Q_i	Quantity of composite good demanded/supplied

Exogenous Variables

$\bar{P}_i$	World price of i^{th} good

Endnotes

1. While this model treats the U.S. economy as a general equilibrium system, it is linked to the rest of the world according to the partial equilibrium functions (3) and (4). To do otherwise would require constructing a general equilibrium model for the entire world.

2. Money-metric is a consumer welfare index. It is equal to the equivalent variation plus base period's expenditure. In the case of the LES demand system we use, it is given by

$$\text{Money-Metric} = \prod_{i=1}^{3} (P_{i0}/P_{i1})^{c_{ih}} (Y_h - T_h)$$

where P_{i0} = Price of good i in the base solution, and P_{i1} = price of good i in the "after-shock" solution. Under closure rule 2, respective composite good prices should be used instead. For further details, see McKenzie (1983).

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