

from three different countries. This study highlights the importance of model design and the structure of the economy for the impact of changes in policy. Peter Dixon's paper analyzes the classic problem of public utility pricing within a general equilibrium setting. The conventional approach to this problem is based on partial equilibrium methods, which ignore the important economy-wide feedbacks of public utility pricing.

The model by Jorgenson and Wilcoxon is a full-fledged econometric model in which the parameters are estimated on the basis of time series data for the United States for the period 1947–85. The model presented by Jorgenson and Wilcoxon is also a complete intertemporal general equilibrium model. Important intertemporal features are also included in the models discussed by Dixon, Benjamin and Andersson. The papers by Bergman and by Jorgenson and Wilcoxon bring in environmental policy as a new field of investigation by numerically implemented general equilibrium models. The model presented by Bergman has already played an important role in the Swedish policy debate over constraints on economic growth imposed by environmental restrictions.

Devarajan, Lewis, and Robinson analyze the properties of a set of static two-sector models. These models incorporate the main features of many of the applied general equilibrium models that have been used for trade and tax policy analyses in developing countries over the past 10–15 years. In particular, they analyze optimal tariffs and common rules of thumb in second-best environments. However, the models can be characterized analytically as well as numerically, thus contributing to a better understanding of the results obtained from large multisector models designed along similar lines.

All the papers in this special issue were presented at the Fourth Task Force Meeting on Applied General Equilibrium Modeling, held at the International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Austria, on August 23–25, 1989. We are very grateful to the Ford Foundation for financial support and to IIASA for arranging the workshop at which these papers were presented. Needless to say, neither of these institutions is responsible in any way for the policy recommendations included in the papers. Lars Bergman was Chairman of the Program Committee and Dale Jorgenson, together with Erno Zalai of the Budapest School of Economics, served as members of the committee for the task force meeting.

## Policy Lessons from Trade-Focused, Two-Sector Models

Shantayanan Devarajan and Jeffrey D. Lewis,  
*Harvard University*

Sherman Robinson, *University of California at Berkeley*

### 1. INTRODUCTION

This article describes how to specify, solve, and draw policy lessons from small, two-sector, general equilibrium models of developing countries. In the last two decades, changes in the external environment and economic policies have been instrumental in determining the performance of these economies. The relationship between external shocks and policy responses is complex. We argue that two-sector models provide a good starting point for analysis because of the nature of the external shocks faced by developing countries in recent years and the policy responses they have elicited. These models capture the essential mechanisms by which external shocks and economic policies ripple through the economy.

By and large, the shocks have involved the external sector: terms of trade shocks, such as the fourfold increase in the price of oil in 1973–1974 or the decline in primary commodity prices in the mid-1980s; or cutbacks in foreign capital inflows. The policy responses most commonly proposed (usually by international agencies) have also been targeted at the external sector: (1) depreciating the real exchange rate to adjust to an adverse terms-of-trade shock or to a cutback in foreign borrowing and (2) reduction in distortionary taxes (some of which are trade taxes) to enhance economic efficiency and make the economy more competitive in world markets.

A “minimalist” model that captures the shocks and policies mentioned above should therefore emphasize the external sector of the economy. Moreover, many of the problems—and solutions—have to

*Address correspondence to Shantayanan Devarajan, Kennedy School of Government, Harvard University, Cambridge, MA 02138*

Received February 1990; accepted September 1990

*Journal of Policy Modeling* 12(4):625–657 (1990)

© Society for Policy Modeling, 1990

do with the relationship between the external sector and the rest of the economy. The model thus should have at least two productive sectors: one producing tradable goods and the other producing nontradables. If an economy produces only traded goods, concepts like a real devaluation are meaningless. Such a country is not able to affect its international competitiveness, because all of its domestic prices are determined by world prices. If a country produced only nontraded goods, it would have been immune to most of the shocks reverberating around the world economy since 1973. Within the category of tradable goods, it is also useful to distinguish importables and exports. Such a characterization enables us to look at terms-of-trade shocks as well as the impact of policy instruments such as import tariffs and export subsidies.

The minimalist model that incorporates these features, while small, captures a rich array of issues. We can examine the impact of an increase in the price of oil (or other import and/or export prices). In addition, this model enables us to look at the use of trade and fiscal policy instruments: export subsidies, import tariffs, and domestic indirect taxes. The implications of increases or decreases in foreign capital inflows can also be studied with this framework.

While the minimalist model captures, in a stylized manner, features characteristic of developing countries, it also yields policy results that cut against the grain of received wisdom. For example, it is not always appropriate to depreciate the real exchange rate in response to an adverse international terms-of-trade shock; reducing import tariffs may not always stimulate exports; unifying tariff rates need not increase efficiency; and an infusion of foreign capital does not necessarily benefit the nontradable sector (in contrast to the results from "Dutch disease" models).

A major advantage of small models is their simplicity. They make transparent the mechanisms by which an external shock or policy change affects the economy. In addition, most of the models presented in this article can be solved analytically, either graphically or algebraically. They also can be solved numerically, and the presentation will introduce the approach used to solve larger, multisector models. Finally, these minimalist two-sector models behave in a fashion similar to that of more complex multisector models, so we can anticipate some of the results obtained from multisector models.

The plan of the article is as follows. In Section 2, we present the simplest of our two-sector models. We specify the equations and discuss some modeling issues. We then analyze the impact of terms-of-trade shocks and changes in foreign capital inflows. In Section 3, we

present a slightly more complex version of the model and use it to discuss some macro issues. In Section 4, we extend the model to include factor markets and intermediate inputs. This expanded model is applied to analyze questions of the optimal choice of tax instruments in a "second-best" situation. The conclusion, Section 5, draws together the main points.

## 2. A TWO-SECTOR, THREE-GOOD MODEL

The basic model refers to one country with two producing sectors and three goods; hence, we call it the *1-2-3 model*. For the time being, we ignore factor markets. The two commodities that the country produces are (1) an export good,  $E$ , which is sold to foreigners and is not demanded domestically, and (2) a domestic good,  $D$ , which is only sold domestically. The third good is an import,  $M$ , which is not produced domestically. There is one consumer who receives all income. The country is small in world markets, facing fixed world prices for exports and imports.

The equation system is presented in Table 1. The model has three actors: a producer, a household, and the rest of the world. Equation 1 defines the domestic production possibility frontier, which gives the maximum achievable combinations of  $E$  and  $D$  that the economy can supply. The function is assumed to be concave and will be specified as a constant elasticity of transformation (CET) function with transformation elasticity  $\Omega$ . The constant,  $\bar{X}$ , defines aggregate production and is fixed. Since there are no intermediate inputs,  $\bar{X}$  also corresponds to real GDP. The assumption that  $\bar{X}$  is fixed is equivalent to assuming full employment of all primary factor inputs. Equation 4 gives the efficient ratio of exports to domestic output ( $E/D$ ) as a function of relative prices. Equation 9 defines the price of the composite commodity and is the cost-function dual to the first-order condition, Equation 4. The composite good price  $P^*$  corresponds to the GDP deflator.

Equation 2 defines a composite commodity made up of  $D$  and  $M$  that is consumed by the single consumer. In multisector models, we extend this treatment to many sectors, assuming that imports and domestic goods in the same sector are imperfect substitutes, an approach that has come to be called the Armington assumption.<sup>1</sup> Following this treatment, we assume the composite commodity is given by a constant elasticity of substitution (CES) aggregation function of  $M$  and  $D$ , with substitution elasticity  $\sigma$ . Consumers maximize utility, which is equiv-

<sup>1</sup>See Armington (1969).

Table 1: The Basic 1-2-3 CGE Model

<b>Flows</b>	<b>Prices</b>
(1) $\bar{X} = G(E, D^s; \Omega)$	(7) $P^m = R \cdot pw^m$
(2) $\bar{Q}^s = F(M, D^o; \sigma)$	(8) $P^c = R \cdot pw^c$
(3) $\bar{Q}^o = \frac{Y}{P^d}$	(9) $P^c = g_1(P^c, P^d)$
(4) $\frac{E}{D^s} = g_2(P^c, P^d)$	(10) $P^d = f_1(P^m, P^c)$
(5) $\frac{M}{D^o} = f_2(P^m, P^c)$	(11) $R \equiv 1$
(6) $Y = P^c \cdot \bar{X} + R \cdot \bar{B}$	
	<b>Equilibrium Conditions</b>
	(12) $D^o - D^s = 0$
	(13) $\bar{Q}^o - \bar{Q}^s = 0$
	(14) $pw^m \cdot M - pw^c \cdot E = \bar{B}$
	<b>Identities</b>
	(i) $P^c \cdot \bar{X} \equiv P^c \cdot E + P^d \cdot D^s$
	(ii) $P^c \cdot \bar{Q} \equiv P^m \cdot M + P^c \cdot D^o$
	(iii) $Y \equiv P^m \cdot Q^o$
<b>Endogenous Variables</b>	
$E$ : Export good	$P^c$ : Price of aggregate output
$M$ : Import good	$P^m$ : Price of composite good
$D^s$ : Supply of domestic good	$R$ : Exchange rate
$D^o$ : Demand for domestic good	<b>Exogenous Variables</b>
$Q^s$ : Supply of composite good	$pw^c$ : World price of export good
$Q^o$ : Demand for composite good	$pw^m$ : World price of import good
$Y$ : Total income	$\bar{B}$ : Balance of trade
$P^c$ : Domestic price of export good	$\sigma$ : Import substitution elasticity
$P^m$ : Domestic price of import good	$\Omega$ : Export transformation elasticity
$P^d$ : Domestic price of domestic good	

alent to maximizing  $Q$  in this model, and Equation 5 gives the desired ratio of  $M$  to  $D$  as a function of relative prices.<sup>2</sup> Equation 10 defines the price of the composite commodity. It is the cost function dual to the first-order conditions underlying Equation 5. The price,  $P^d$ , corresponds to an aggregate consumer price or cost-of-living index.

Equation 6 determines household income. Equation 3 defines house-

<sup>2</sup>In the multisector models, we add expenditure functions with many goods based on utility maximization at two levels. First, allocate expenditure among goods. Second, decide on sectoral import ratios. In the 1-2-3 model, the CES function defining  $Q$  can be treated as a utility function (see eq. 4).

Table 2: The 1-2-3 Model as a Programming Problem

Maximize $Q = F(M, D^o; \sigma)$ with respect to: $M, E, D^o, D^s$ subject to:	(absorption)	
(a) $G(E, D^s; \Omega) \leq \bar{X}$	(technology)	Shadow Price $\lambda^x = P^c/P^d$
(b) $\frac{pw^m}{B} + M \leq pw^c \cdot E$	(balance of trade)	$\lambda^b = R/P^d$
(c) $D^o \leq D^s$	(domestic supply and demand)	$\lambda^d = P^c/P^d$

where constraints a-c correspond to Equations, 1, 14, and 12 in Table 1.

hold demand for the composite good. Note that all income is spent on the single composite good. Equation 3 stands in for the more complex system of expenditure equations found in multisector models and reflects an important property of all complete expenditure systems: The value of the goods demanded must equal aggregate expenditure.

In Table 1, the price equations define relationships among seven prices. There are fixed world prices for  $E$  and  $M$ ; domestic prices for  $E$  and  $M$ ; the price of the domestic good  $D$ ; and prices for the two composite commodities,  $X$  and  $Q$ . Equations 1 and 2 (Table 1) are linearly homogeneous, as are the corresponding dual price Equations, 9 and 10. Equations 3-5 are homogeneous of degree zero in prices: Doubling all prices, for example, leaves real demand and the desired export and import ratios unchanged.<sup>3</sup> Because only relative prices matter, it is necessary to define a numeraire price; in Equation 11, this is specified to be the exchange rate,  $R$ .

Equations 12, 13, and 14 define the market-clearing equilibrium conditions. Supply must equal demand for  $D$  and  $Q$ , and the balance-of-trade constraint must be satisfied. The complete model has 14 equations and 13 endogenous variables. The three equilibrium conditions, however, are not all independent. Any one of them can be dropped and the resulting model is fully determined.

To prove that the three equilibrium conditions are not independent, it suffices to show that the model satisfies Walras's Law. Such a model is "closed" in that there are no leakages of funds into or out of the economy. First note the three Identities (i, ii, and iii) that the model

<sup>3</sup>For the demand equation, one must show that nominal income doubles when all prices double, including the exchange rate. By tracing the elements in Equation 6, it is easy to demonstrate that nominal income goes up proportionately with prices.

satisfies. The first two arise from the homogeneity assumptions and the third from the fact that, in any system of expenditure equations, the value of purchases must equal total expenditure.<sup>4</sup> Multiplying Equations 12 and 13 by their respective prices, the sum of Equations 12, 13, and 14 equals zero as an identity (moving  $B$  in Equation 14 to the left side). Given these identities, simple substitution will show that if Equations 12 and 13 hold, then so must 14.

The 1-2-3 model is different from the standard neoclassical trade model with all goods tradable and all tradables perfect substitutes with domestic goods. The standard model, long a staple of trade theory, yields wildly implausible results in empirical applications.<sup>5</sup> Empirical models that reflect these assumptions embody "the law of one price," which states that domestic relative prices of tradables are set by world prices. Such models tend to yield extreme specialization in production and unrealistic swings in domestic relative prices in response to changes in trade policy or world prices. Empirical evidence indicates that changes in the prices of imports and exports are only partially transmitted to the prices of domestic goods. In addition, such models cannot exhibit two-way trade in any sector ("cross hauling"), which is often observed at fine levels of disaggregation.

Recognizing these problems, Salter (1959) and Swan (1960) specified a two-sector model that distinguishes "tradables" (including both imports and exports) from "nontradables." Their approach represented an advance and their articles started an active theoretical literature. However, they had little impact on empirical work. Even in an input-output table with over 500 sectors, there are very few sectors that are purely nontraded, that is, with no exports or imports. So defined, nontraded goods are a very small share of GDP; and, in models with 10-30 sectors, there would be at most only one or two nontraded sectors. Furthermore, the link between domestic and world prices in the Salter-Swan model does not depend on the trade share, but only on whether the sector is tradable. If a good is tradable, regardless of how small the trade share, the domestic price will be set by the world price.

The picture is quite different in the 1-2-3 model with imperfect substitutability and transformability. All domestically produced goods that are not exported ( $D$  in Table 1) are effectively treated as nontradables (or, better, as "semitradables"). The share of nontradables

<sup>4</sup>In this model Equation 3 and Identity iii are the same. In a multisector model, as noted above, Identity iii is a necessary property of any system of expenditure equations.

<sup>5</sup>Empirical problems with this specification have been a thorn in the side of modelers since the early days of linear programming models. For a survey, see Taylor (1975).

in GDP now equals one minus the export share, which is a very large number, and all sectors are treated symmetrically. In effect, the specification in the 1-2-3 model extends and generalizes the Salter-Swan model, making it empirically relevant.

De Melo and Robinson (1985) show, in a partial equilibrium framework, that the link between domestic and world prices, assuming imperfect substitutability at the sectoral level, depends critically on the trade shares, both for exports and imports, as well as on elasticity values. For given substitution and transformation elasticities, the domestic price is more closely linked to the world price in a given sector the greater are export and import shares. In multisector models, the effect of this specification is a realistic insulation of the domestic price system from changes in world prices. The links are there, but they are not nearly as strong as in the standard neoclassical trade model. Also, the model naturally accommodates two-way trade, because exports, imports, and domestic goods in the same sector are all distinct.

For a single-country model, the CES and CET functions capture the reasonable notion that it is not easy to shift trade shares in either export or import markets. Given that each sector has seven associated prices, the model provides for a lot of product differentiation. The assumption of imperfect substitutability on the import side has been widely used in empirical models.<sup>6</sup> Note that it is equally important to specify imperfect transformability on the export side. Without imperfect transformability, the law of one price would still hold for all sectors with exports. In the 1-2-3 model, both import demand and export supply depend on relative prices.<sup>7</sup>

De Melo and Robinson (1989) analyze the properties of this model in some detail and argue that it is a good stylization of most recent

<sup>6</sup>The CES formulation for the import-aggregation function has been criticized on econometric grounds (see Allston et al. (1989) for an example). It is certainly a restrictive form. For example, it constrains the income elasticity of demand for imports to be unity in every sector. Rather than complete rejection of approaches relying on imperfect substitutability, this criticism would seem to suggest that it is time to explore the many alternative functional forms that are available. For example, Hanson, Robinson, and Lokarick (1989) estimate sectoral import demand functions based on the almost ideal demand system (AIDS) formulation. They find that sectoral expenditure elasticities of import demand are generally much greater than unity in the United States, which results are consistent with estimates from macroeconomic models. Factors other than relative prices appear to affect trade shares, and it is important to study what they might be and how they operate.

<sup>7</sup>Dervis, de Melo, and Robinson (1982) specify a logistic export supply function in place of Equation 4 in Table 2. Their logistic function is locally equivalent to the function that is derived from the CET specification.

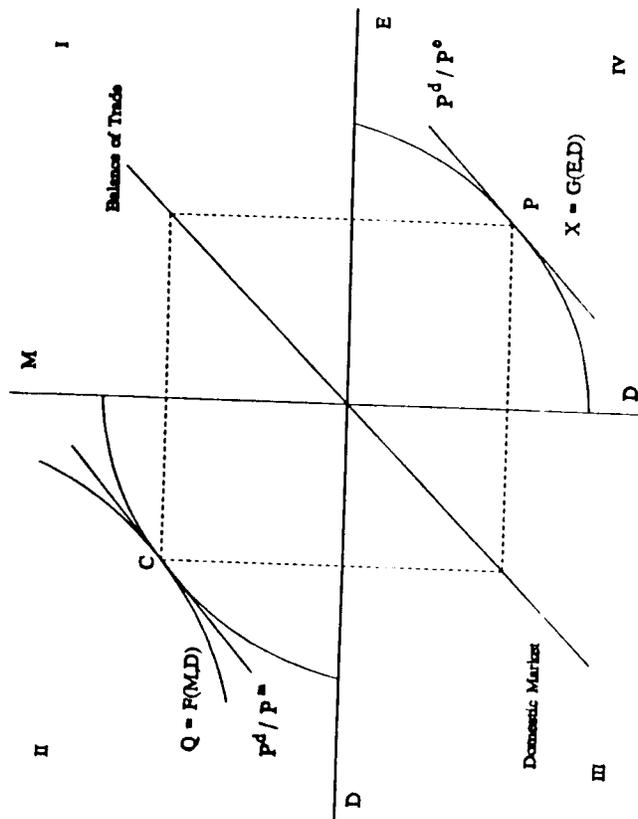


Figure 1. The 1-2-3 programming model.

single-country, trade-focused, CGE models. Product differentiation on both the import and export sides is very appealing for applied models, especially at the levels of aggregation typically used. The specification is a faithful extension of the Salter-Swan model and gives rise to normally shaped offer curves. The exchange rate is a well-defined relative price. If the domestic good is chosen as the numeraire commodity, setting  $P^d$  equal to unity, then the exchange rate variable,  $R$ , corresponds to the real exchange rate of neoclassical trade theory: the relative price of tradables ( $E$  and  $M$ ) to nontradables ( $D$ ). Trade theory models (and our characterization in Table 1) often set  $R$  to unity, with  $P^d$  then defining the real exchange rate. For other choices of numeraire,  $R$  is a monotonic function of the real exchange rate.<sup>8</sup>

The 1-2-3 model can also be seen as a simple programming model. This formulation is given in Table 2, and is shown graphically in Figure 1. The presentation emphasizes the fact that a single-consumer general equilibrium model can be represented by a programming model

that maximizes consumer utility, which is equivalent to social welfare.<sup>9</sup> In this model, the shadow prices of the constraint equations correspond to market prices in the CGE model.<sup>10</sup> We will use the graphical apparatus to analyze the impact of two shocks: an increase in foreign capital inflow and a change in the international terms of trade.<sup>11</sup> We will also use this programming-model formulation, including endogenous prices and tax instruments, to derive optimal policy rules under second-best conditions.

The transformation function (Equation 1 in Table 1 and constraint a in Table 2) can be depicted in the fourth (southeast) quadrant of the four-quadrant diagram in Figure 1. For any given price ratio  $P^d/P^m$ , the point of tangency with the transformation frontier determines the amounts of the domestic and exported good that are produced. Assume, for the moment, that foreign capital inflow  $B$  is zero. Then constraint b, the balance-of-trade constraint, is a straight line through the origin, as depicted in the first quadrant of Figure 1. If we assume for convenience that all world prices are equal to unity, then the slope of the line is unity. For a given level of  $E$  produced, the balance-of-trade constraint determines how much of the imported good the country can buy. It is intuitively clear that, with no capital inflows ( $B = 0$ ), the only source of foreign exchange is exports. The second quadrant shows the "consumption possibility frontier," which represents the combinations of the domestic and imported good that the consumer can buy, given the production technology as reflected in the transformation frontier and the balance-of-trade constraint. When world prices are equal and trade is balanced, the consumption possibility frontier is the mirror image of the transformation frontier. Equation 2 in Table 1 defines "absorption," which is maximized in the programming problem. The tangency between the "iso-absorption" (or indifference) curves and the consumption possibility frontier will determine the amount of  $D$  and  $M$  the consumer will demand, at price ratio  $P^d/P^m$ . The economy produces at point  $P$  and consumes at point  $C$ .

Now consider what would happen if foreign capital inflow increased from its initial level of zero to some value  $B > 0$ . For example, the

<sup>9</sup>Ginsburgh and Waelbroeck (1981) discuss, in detail, the general case where a multicountry CGE model can be represented by a programming model maximizing a Negishi social welfare function. See also Ginsburgh and Robinson (1984) for a brief survey of the technique applied to CGE models.

<sup>10</sup>In the programming model, we implicitly choose  $Q$  as the numeraire good, with  $P^m \equiv 1$ . In the graphical analysis, we set  $R \equiv 1$ .

<sup>11</sup>The discussion follows de Melo and Robinson (1989).



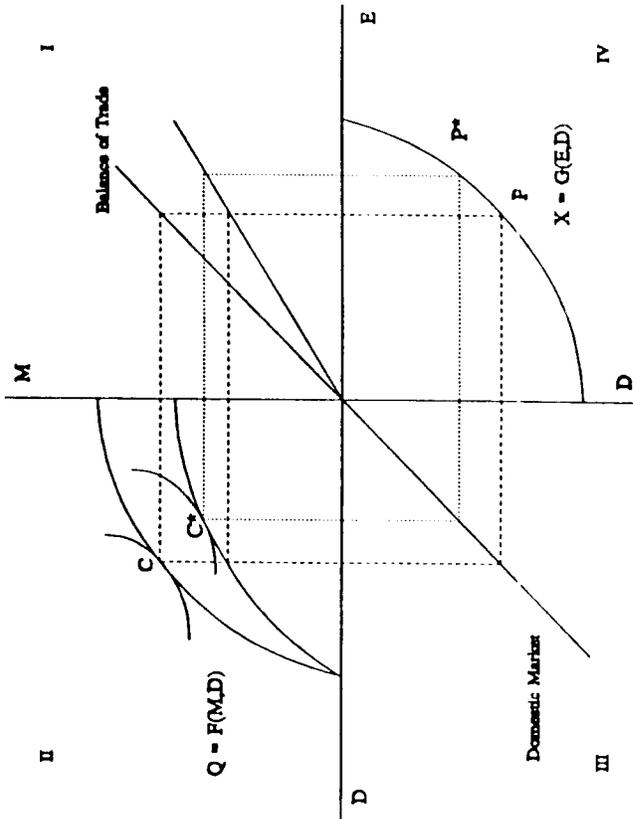


Figure 3. Change in world prices.

tangent to the new consumption possibility frontier to the left of the old consumption point (C), because the rotation flattened the curve. At the new point, output of D rises and the real exchange rate appreciates. When  $\sigma = 1$ , there is no change in either the real exchange rate or the production structure of the economy. The intuition behind this somewhat unusual result is as follows.<sup>13</sup> When the price of imports rises in an economy, there are two effects: an income effect (as the consumer's real income is now lower) and a substitution effect (as domestic goods now become more attractive). The resulting equilibrium will depend on which effect dominates. When  $\sigma < 1$ , the income effect dominates. The economy contracts output of the domestic good and expands that of the export commodity. In order to pay for the needed, nonsubstitutable import, the real exchange rate depreciates. However, when  $\sigma > 1$ , the substitution effect dominates. The response of the economy is to contract exports (and hence also imports) and produce more of the domestic substitute.

For most developing countries, it is likely that  $\sigma < 1$ , so that the standard policy advice to depreciate the real exchange rate in the wake of an adverse terms-of-trade shock is correct. For developed economies, one might well expect substitution elasticities to be high. In this case, the response to a terms-of-trade shock is a real revaluation, substitution of domestic goods for the more expensive (and noncritical) import, and a contraction in the aggregate volume of trade. In all countries, one would expect substitution elasticities to be higher in the long run. The long-run effect of the real exchange rate will thus differ, and may be of opposite sign, from the short-run effect.

The relationship between the response of the economy to the terms-of-trade shock and the elasticity of substitution can also be seen by solving the model algebraically. By considering only small changes to the initial equilibrium, we can linearize the model and obtain approximate analytical solutions. We follow this procedure to analyze the impact of a terms-of-trade shock.<sup>14</sup>

Let a ("...") above a variable denote its log-differential. That is,  $\hat{z} = d(\ln z) = dz/z$ . Log-differentiate Equations 4, 5, and 14 in Table 1, assuming an exogenous change in the world price of the import. The results are:

$$\hat{E} - \hat{D} = \Omega \cdot \hat{P}^d;$$

$$\hat{M} - \hat{D} = \sigma (\hat{P}^d - \hat{p}_w^m);$$

$$\hat{M} + \hat{p}_w^m = \hat{E}.$$

Eliminating  $\hat{M}$ ,  $\hat{D}$ , and  $\hat{E}$  and solving for  $\hat{P}^d$  gives

$$\hat{P}^d = \frac{\sigma - 1}{\sigma + \Omega} \hat{p}_w^m.$$

Thus, whether  $P^d$  increases or decreases in response to a terms-of-trade shock depends on the sign of  $(\sigma - 1)$ , confirming the graphical analysis discussed above. Note that the direction of change in  $P^d$  will determine how the rest of the economy will adjust in this counterfactual experiment. If  $P^d$  falls (the real exchange rate depreciates), exports will rise and production of the domestic good will fall.

Our analysis with the 1-2-3 model has yielded several lessons.

<sup>14</sup>De Melo and Robinson (1989) derive the closed-form solution for the country's offer curve in the 1-2-3 model. A more complete discussion and mathematical derivation is given in Devarajan, Lewis, and Robinson (1990).

First, the bare bones of multisector general equilibrium models are contained in this small model. Second, and perhaps more surprisingly, this two-sector model is able to shed light on some issues of direct concern to developing countries. For example, the appreciation of the real exchange rate from a foreign capital inflow, widely understood intuitively and derived from more complex models, can be portrayed in this simple model. In addition, results from this small model challenge a standard policy dictum: Always depreciate the real exchange rate when there is an adverse terms-of-trade shock. The model shows the conditions under which this policy advice should and should not be followed.

Of course, many aspects of the economy are left out of the small model. In particular, there is no government. If a model is to be useful for policy analysis, it should contain the relevant policy instruments and actors. In the next section, we extend the 1-2-3 model to include them.

### 3. THE 1-2-3 MODEL WITH GOVERNMENT AND INVESTMENT

Up to now, the focus has been on adjustments in the real exchange rate in response to exogenous shocks to the economy. However, the real exchange rate is not an instrument that the government directly controls. Rather, most governments use taxes and subsidies as well as expenditure policy to adjust their economies. The model presented in the previous section did not explicitly incorporate these fiscal instruments. Nor did it include important components that would allow consideration of macroeconomic issues such as the relationships among macro aggregates. Table 3 presents an extended version of the 1-2-3 model to include government revenue and expenditure and also savings and investment. Three price-wedge government policy instruments are included: an import tariff, an export subsidy, and an indirect tax on domestic sales. In addition, savings and investment are included. The single household saves a fraction of its income. Real government expenditure is assumed fixed and the government deficit or surplus is subtracted or added to aggregate savings. Finally, the balance of trade is assumed to represent foreign savings.

#### 3A. The Model in a Social Accounting Matrix

Equations 6 to 9 in Table 3 determine the income flows in the economy. The model has four actors: a producer, a household, government, and the rest of the world. Equation 6 determines government

**Table 3:** The 1-2-3 Model with Government and Investment

Real Flows		Prices	
(1) $\bar{X} = G(E, D^S, \Omega)$		(10) $P^m = (1 + t^m) \cdot R \cdot p_w^m$	
(2) $Q^S = F(M, D^D, \sigma)$		(11) $P^e = (1 + t^e) \cdot R \cdot p_w^e$	
(3) $Q^D = C/P^d + Z + \bar{G}$		(12) $P^i = (1 + t^i) \cdot P^d$	
(4) $E/D^S = g_1(P^e, P^d)$		(13) $P^s = g_2(P^e, P^d)$	
(5) $M/D^D = f_1(P^m, P^e)$		(14) $P^w = f_2(P^m, P^e)$	
		(15) $R = 1$	
Nominal Flows		Equilibrium Conditions	
(6) $T = t^m \cdot R \cdot p_w^m \cdot M$		(16) $D^D \cdot D^S = 0$	
+ $t^e \cdot P^d \cdot D^D$		(17) $Q^D - Q^S = 0$	
- $t^i \cdot R \cdot p_w^e \cdot E$		(18) $p_w^m \cdot M - p_w^e \cdot E = \bar{B}$	
(7) $Y = P^s \cdot \bar{X}$		(19) $P^d \cdot Z - S = 0$	
(8) $S = \bar{s} \cdot Y + R \cdot \bar{B} + S^e$		(20) $T \cdot P^d \cdot \bar{G} - S^e = 0$	
(9) $C = Y - \bar{s} \cdot Y$			
Accounting Identities			
	(i) $P^s \cdot \bar{X} = P^e \cdot E + P^d \cdot D^S$		
	(ii) $P^w \cdot Q^S = P^m \cdot M + P^e \cdot D^D$		
	(iii) $P^d \cdot Q^D = C + P^d \cdot Z + P^w \cdot \bar{G}$		
Endogenous Variables			
$E$ :	Export good	$C$ :	Aggregate consumption
$M$ :	Import good	$S$ :	Aggregate savings
$D^S$ :	Supply of domestic good	$Z$ :	Aggregate real investment
$D^D$ :	Demand for domestic good	Exogenous Variables	
$Q^S$ :	Supply of composite good	$p_w^m$ :	World price of import good
$Q^D$ :	Demand for composite good	$p_w^e$ :	World price of export good
$P^e$ :	Domestic price of export good	$t^m$ :	Tariff rate
$P^m$ :	Domestic price of import good	$t^e$ :	Export subsidy rate
$P^d$ :	Producer price of domestic good	$t^i$ :	Indirect tax rate
$P^s$ :	Consumer price of domestic good	$\bar{s}$ :	Average savings rate
$P^w$ :	Price of aggregate output	$\bar{X}$ :	Aggregate output
$P^e$ :	Price of composite good	$\bar{G}$ :	Real government demand
$R$ :	Exchange rate	$\bar{B}$ :	Balance of trade
$T$ :	Net government revenue	$\Omega$ :	Export transformation elasticity
$S^e$ :	Government savings	$\sigma$ :	Import substitution elasticity
$Y$ :	Total income		

revenue (net of export subsidies) and Equation 7 determines household income. Equations 8 and 9 determine total savings and aggregate household consumption. The nominal flows among the actors can be tabulated in a social accounting matrix (SAM), which is presented in Figure

4.<sup>15</sup> The SAM shows the circular flow of income and expenditure in the economy. Each cell represents a payment from a column account to a recipient in a row account. The SAM is square and, following the conventions of double-entry bookkeeping, each actor's accounts must balance: Income must exactly equal expenditure. Thus, column sums in the SAM must equal the corresponding row sums.

The present SAM defines six accounts, one for each actor, one for savings and investment, and an additional "commodity" account. The commodity account keeps track of absorption, which equals the value of domestic products sold on the domestic market,  $D$ , and imports,  $M$ . The producer account pays out total revenue to households and government down the column and sells goods on the domestic and foreign markets along the row. The column sum equals GDP at market prices, which includes indirect taxes. GDP at factor cost equals  $P^s \cdot X$  and is paid out to households. Export subsidies are seen as a payment by government to producers. Exports and imports in the account for the rest of the world are valued in world market prices times the exchange rate.

The capital account in the SAM reflects savings—investment balance. It summarizes the workings of the financial system, representing the net loanable funds market. It collects savings along the row and spends them on investment goods in the column. The allocation of new capital goods by sector of destination is not shown. The model thus captures the savings—investment nexus in a stylized manner and also includes other macro aggregates. As we show below, it can provide a framework for some macro analysis.

### 3B. Macro Closure

The macroeconomic properties of CGE models of developing countries have provided a topic for much debate and controversy. The discussion has focused on what has come to be called the "macro closure" of an economywide model.<sup>16</sup> As the SAM indicates, the extended 1-2-3 model contains the three basic macro balances: balance of trade, savings—investment, and government deficit. In this model, the balance of trade is fixed and real government expenditure is fixed. The government deficit is determined residually as expenditure minus

<sup>15</sup> Pyatt and Round (1985) provide a good introduction to SAMs and a number of examples of their uses.

<sup>16</sup> The seminal work on closure is Sen (1963). The development literature is surveyed by Raitovici (1982) and by Robinson (1989a).

Figure 4: Social Accounting Matrix for 1-2-3 Model with Government and Investment

		Expenditures					
Receipts	Commodity	Producer	Household	Government	Capital	World	Total
Commodity	$P^c \cdot D^c$	$C$	$C$	$P^g \cdot G$	$P^z \cdot Z$	$E$	$P^c \cdot \bar{Q}^c + P^s \cdot E$
Producer	$P^p \cdot X^p$						$P^p \cdot X^p + P^s \cdot E$
Household	$T^h$						$T^h$
Government	$M$						$M$
Capital account							
Rest of world							
Total	$P^c \cdot \bar{Q}^c$	$GDP + T^h$	$Y$	Outflow	$P^z \cdot Z$	$E + R \cdot \bar{B}$	

Definitions:  
 $M = R \cdot p^{w*} \cdot M$   
 $E = R \cdot p^{w*} \cdot E$   
 $T^h = R \cdot p^{w*} \cdot E$   
 $GDP = P^s \cdot X = GDP$  at factor cost  
 $P^c \cdot \bar{X} + T^h - T^p + C + P^g + \bar{G} + P^z \cdot Z + E - M = GDP$  at market prices  
 All other variables are defined in Table 3.

net tax receipts. Aggregate savings is the sum of household saving, government saving (surplus), and the balance of trade (foreign saving). There is no separate investment function, so aggregate investment is simply equal to aggregate savings. This savings-driven investment determination represents a macro specification that is called "neoclassical closure."

In addition, the model implicitly assumes full employment, so aggregate real GDP ( $\bar{X}$  in Equation 1) is fixed. While all the macro balances are in the model, there is little room for any interesting macro behavior. There is no possible feedback from changes in macro aggregates to GDP and little scope for variation in the macro aggregates themselves. Given the assumed savings behavior, no special equilibrating variable is required to achieve savings-investment equilibrium. The model is specified in terms only of current flows and flow-equilibrium conditions. There are no assets, no asset markets, no money, no expectations, and no dynamics.

The extended 1-2-3 model represents a Walrasian CGE model. While it contains macro aggregates, as must any economywide model, it is best seen as a neoclassical general equilibrium model of production and exchange. The additions of government, savings-investment, and the balance of trade are done in ways that retain the notion of flow equilibria and do not strain the Walrasian paradigm. However, as the development literature illustrates, it is possible to bring in a lot of macro effects while remaining within the framework of a CGE model that includes only flow variables.

The literature on macro closure has followed two different approaches to bringing macro features into the model. In the first approach, relationships are specified among the macro aggregates, but their justification is based on macroeconomic theory outside of the CGE model. At one extreme, all the macro variables are specified as exogenous to the model.<sup>17</sup> In a second approach, the CGE model is extended to include variables typically found in macro models (such as money, assets, and interest rates) and to expand the notion of equilibrium to incorporate asset markets and expectations. The intent is to build CGE models that move beyond the Walrasian paradigm and directly incorporate macro phenomena.<sup>18</sup>

In the first approach, in effect, the CGE model is forced to interact

<sup>17</sup>Or almost all. The CGE model still must satisfy Walras's Law and the various equilibrium conditions are not all independent. For an example of a CGE model which draws on a separate macro model to determine the macro aggregates, see Hanson, Robinson, and Tokarick (1989).  
<sup>18</sup>Devarajan and Michel (1987) argue for this approach.

with a macro model, but the two models are kept as separate as possible. The macro model may not even be fully spelled out. The basic credo of this approach might be described as "Render unto Walras that which belongs to Walras, and ditto for Keynes." This approach has been widely used in CGE models of developing countries and in a few models of developed countries.<sup>19</sup>

A recent example is provided by Devarajan and de Melo (1987), who discuss a CGE model applicable to franc zone African countries. In these countries, the local currency is tied to the French franc, so they have no independent monetary authority. In addition, it is reasonable to assume that government expenditure and aggregate investment are fixed exogenously. Given fixed tax rates, government revenue and private savings may not suffice to finance government expenditure and aggregate investment. Any shortfall is financed by foreign borrowing. In effect, for these countries the French Central Bank finances the sum of the twin deficits.<sup>20</sup>

The extended 1-2-3 model can easily be adapted to incorporate these assumptions. In Table 3, fix aggregate real investment as well as real government expenditure. The model is now investment-driven rather than savings-driven. To achieve savings-investment equilibrium, the balance of trade is now treated as an endogenous variable. It is the macro equilibrating variable that will vary to equate savings (the sum of private, government, and foreign savings) and investment. The nominal exchange rate is chosen as numeraire, reflecting the fact that the exchange rate in these countries is tied to the French franc. The domestic price level will vary to produce a real exchange rate that generates a balance of trade that achieves macro balance. The CGE model will thus solve for a flow equilibrium that is consistent with the assumed macro behavior. The model incorporates macro rigidities, in particular the government revenue constraint. If government revenue changes, say by changing taxes, the effect will be to change the balance of trade because the government deficit is financed by foreign borrowing.

<sup>19</sup>See Powell (1981), who describes how the Orani model of Australia was linked to a separate small macro model. Robinson and Tyson (1984) formally describe the notion of linking macro and CGE models and relate the idea to the literature on macro closure. Many of the structural adjustment models of developing countries that trace their roots to Dervis, de Melo, and Robinson (1982) are in this tradition.

<sup>20</sup>Such a view may seem extreme. However, consider recent U.S. history. While the macro story is more complex, the net result is essentially the same. The United States has financed the federal deficit by foreign borrowing, the Japanese playing the role of the French Central Bank.

Given the focus on the government budget, the model can be further simplified by setting aggregate real investment to zero. Devarajan and de Melo assume that real government demand for the domestic good is fixed and add the balance of trade directly to government revenue. The macro equilibrating mechanism is unchanged, with the government deficit directly linked to the balance of trade.

Unfortunately, even with these simplifying assumptions, this model does not lend itself to the same four-quadrant, diagrammatic analysis used above. Given the assumption that the current account is determined endogenously, any change in consumption or production that changes government revenue will also change the balance of trade (shifting the balance of trade constraint line in Figure 1). Any shock will likely have a compound effect, shifting curves in more than one quadrant.<sup>21</sup> The model, however, does yield analytic results analogous to those from the 1-2-3 model. This model indicates that these economies might well react in ways counterintuitive to some standard policy packages.

Consider, for example, the effect of an increase in the tariff rate. The initial effect is a rotation of the consumer's budget line, making imports more expensive. In the 1-2-3 model with a fixed balance of trade, the final result would be lower import demand, appreciation of the exchange rate, an incentive bias against exports, and lower exports. An import tariff represents a tax on exports—a proposition known as Lerner symmetry. In the Devarajan-de Melo model, however, macro feedbacks can change this result. The increase in the tariff rate increases government revenue, thus lessening foreign borrowing and improving the balance of trade. The lower balance of trade generates a real depreciation, offsetting the real appreciation associated with the tariff increase, and encouraging exports ( $E$ ). Whether exports actually increase depends on  $\sigma$ , the elasticity of substitution between the import ( $M$ ) and domestic good ( $D$ ). The reason is that, in this model, none of the tariff revenue is transferred to the consumer. Instead, it is used to reduce foreign borrowing. Thus, when the tariff rate is increased, the consumer faces a higher domestic price for  $M$ , with no change in income. When  $\sigma > 1$ , the consumer buys more  $D$  and less  $M$ . However, if  $\sigma < 1$ , the consumer buys less of both goods. The lower consumption of  $D$  releases resources to the exportable sector, raising  $E$ . The coun-

<sup>21</sup>Devarajan and de Melo (1987) present an alternative diagrammatic approach for analyzing simple shocks with this model.

terintuitive result in this case is that the tariff increase leads to a rise in exports.

Finally, consider the impact of a change in the international terms of trade; for example, an increase in the world price of exports. In the 1-2-3 model, with a fixed balance of trade, the new equilibrium will have an increase in absorption  $Q$  (and hence in welfare). As discussed above, what happens to the volume of exports and imports, and to domestic relative prices, depends on the elasticity of substitution  $\sigma$ . The increase in the price of exports generates an income effect as well as a substitution effect. Income goes up, leading to an increase in demand for both  $D$  and  $M$ . If  $\sigma$  is less than unity, the income effect dominates and, in the final equilibrium, consumption of both domestic goods and imports ( $D$  and  $M$ ) will be higher and exports lower, and the real exchange rate will appreciate. In the Devarajan-de Melo model, however, there is a second macro income effect. Appreciation of the real exchange rate raises the price of  $D$ . An increase in  $P^d$  will increase the cost of fixed government demand for  $D$ , worsening the government budget deficit, and leading to increased foreign borrowing.<sup>22</sup> The net effect is that the balance of trade deteriorates, with greater appreciation of the final equilibrium real exchange rate. Thus, with  $\sigma < 1$ , the net effect of a beneficial increase in export prices is to worsen the balance of trade. Devarajan and de Melo cite empirical evidence that indicates that this outcome is consistent with the behavior of many franc zone African countries.

In the Devarajan-de Melo model, the macro effects are purely structural in the sense that they affect only the composition of the economy. Given the maintained assumption that factors are fully employed and that factor markets clear, the changes in macro aggregates will have little or no effect on aggregate real GDP. Many of the structural adjustment models maintain the assumption of full employment. There is, however, a strand of work with CGE models that incorporates mechanisms that permit changes in macro aggregates to generate unemployment. For example, Devarajan and de Melo specify a variant of their model with a fixed wage, thus allowing aggregate employment effects in response to shocks. These "macro structuralist" models all have in common the assumption that at least some factor and product

<sup>22</sup>There is a countervailing effect because, as imports rise, so does tariff revenue. The effect is not large enough to offset the increase in the price of the domestic good. This result is sensitive to the assumption that government demands only the domestic good.

markets do not clear.<sup>23</sup> They postulate various rigidities, such as sectorally immobile capital, fixed wages, mark-up pricing, a fixed exchange rate, and/or various kinds of rationing in product and factor markets. They can generate Keynesian unemployment (or Keynesian closure) and so postulate strong links between macro balances and the real side of the economy.

The literature on macro closure demonstrates that neoclassical CGE models that contain no assets or money can still be useful in analyzing the impact of changes in macro aggregates on the economy. However, the marriage is an uneasy one. A macro model or scenario is forced onto the CGE model, which then traces out the structural implications of the assumed macro behavior. There are no optimizing agents (either private or government) that generate the macro behavior. The macro structuralist models further strain the neoclassical paradigm because they assume that various markets do not clear and that certain agents within the model economy do not optimize.

Introducing taxes, subsidies, and government expenditure adds more than just missing instruments and macroeconomic behavior to the two-sector model. It captures a fundamental fact in public economics: It is costly to transfer resources from the private to the public sector. Since governments do not have access to lump-sum taxes, they must use second-best taxes, which by definition distort incentives and create efficiency losses in the economy. One goal of structural adjustment policy often expressed in World Bank and IMF reports is to reduce these distortions and improve the allocation of resources. Nevertheless, governments continue to need revenue so that eliminating all taxes is not an option. In the next section, we extend the 1-2-3 model further to include factor markets and intermediate goods, and then use this model to determine optimal taxes under various second-best scenarios. As we will see, some of the policy rules of thumb do not necessarily improve the efficiency of the economy.

#### 4. A TWO-SECTOR MODEL WITH FACTOR MARKETS AND INTERMEDIATE GOODS

When considering the efficiency effects of tax policy, it is critical to distinguish between intermediate and final goods. The models presented earlier do not make this distinction. In this section, we extend

<sup>23</sup> Lance Taylor is a leader in this field. See Taylor (1983). Recent CGE models in this tradition with a focus on agriculture are surveyed by de Lanery and Sadoulet (1987). Adelman and Robinson (1977) compare various macro closures in two-sector models.

**Table 4:** The 1-2-3 Model with Factor Markets and Intermediate Inputs

Flows	Prices
(1) $E = E(K_c, L_c, N_c)$	(16) $P^c = R \cdot (1 + t^c) \cdot pw^c$
(2) $D = D(K_d, L_d, N_d)$	(17) $P^d = f_3(p_n^m, p^d)$
(3) $Q^s = Q(M_g, D_g)$	(18) $P^g = f_3(p_n^m, p^g)$
(4) $N = N(M_n, D_n)$	(19) $P_n^m = R \cdot (1 + t_n^m) \cdot pw_n^m$
(5) $\frac{M_g}{D_g} = f_1(p_n^m, p^g)$	(20) $P_n^m = R \cdot (1 + t_n^m) \cdot P^d$
(6) $\frac{M_n}{D_n} = f_1(p_n^m, p^g)$	(21) $P^c = P^d - a_c \cdot P_n$
(7) $N_c = a_c \cdot E$	(22) $P^d = P^d - a_d \cdot P_n$
(8) $N_d = a_d \cdot D$	(23) $P^g = P^g - a_g \cdot P_n$
(9) $W_k = \frac{\partial E}{\partial K_c} P^c$	Equilibrium Conditions
(10) $W_k = \frac{\partial D}{\partial K_d} P^d$	(24) $D_g + D_n - D = 0$
(11) $W_l = \frac{\partial E}{\partial L_c} P^c$	(25) $Q^s - Q^d = 0$
(12) $W_l = \frac{\partial D}{\partial L_d} P^d$	(26) $N_c + N_d - N = 0$
(13) $Y = W_k \cdot \bar{K} + W_l \cdot \bar{L} + R \cdot \bar{B} + G$	(27) $L_c + L_d - \bar{L} = 0$
(14) $Q^p = \frac{Y}{P^g}$	(28) $K_c + K_d - \bar{K} = 0$
(15) $T = t^c \cdot P^c \cdot D - t^d \cdot pw^d \cdot E \cdot R + t_n^g \cdot pw_n^m \cdot M_g \cdot R + t_n^d \cdot pw_n^m \cdot M_n \cdot R$	(29) $pw_n^m \cdot M_g + pw_n^m \cdot M_n - pw_n^c \cdot E = \bar{B}$
	(30) $T - G = 0$
	(31) $R = 1$

#### Identities

- (i)  $P^g \cdot Q^s = P_n^m \cdot M_g + P^c \cdot D_g$
- (ii)  $P^g \cdot N = P_n^m \cdot M_n + P^c \cdot D_n$
- (iii)  $P^g \cdot Q^p = Y$
- (iv)  $P^c \cdot E = W_l \cdot L_c + W_k \cdot K_c$
- (v)  $P^d \cdot D = W_l \cdot L_d + W_k \cdot K_d$

(continued)

the model to introduce imported and domestic intermediate goods ( $M_n$  and  $D_n$ ) and also production functions that use primary factors of production (capital and labor) to produce domestic goods and exports ( $D$  and  $E$ ).

Table 4 presents the equations of the 1-2-3 model with factor markets and intermediate inputs. The model contains most of the features of

Table 4 (continued)

Endogenous Variables	
$E$ : Export good	$P^i$ : Price of intermediate input
$D$ : Supply of domestic good	$P^c$ : Price of composite good
$N_d$ : Intermediate demand by E	$W_K$ : Return to capital
$N_d$ : Intermediate demand by D	$W_L$ : Wage rate
$N$ : Supply of composite intermediate input	$R$ : Exchange rate
$Q^c$ : Supply of composite final good	$Y$ : Total income
$Q^d$ : Demand for composite final good	$T$ : Tax revenue
$D_d$ : D used in consumption	$G$ : Government transfers
$D_d$ : D used in intermediate inputs	
$K$ : Capital used to produce E	Exogenous Variables
$L$ : Labor used to produce E	$\bar{L}$ : Total labor supply
$K_d$ : Capital used to produce D	$\bar{K}$ : Total capital stock
$L_d$ : Labor used to produce D	$B$ : Balance of trade
$M_d$ : Imports used in consumption	$pW^e$ : World price of export good
$M_d$ : M used in intermediate demand	$\bar{p}W_d^e$ : World price of consumption imports
$P^e$ : Export price	$\bar{p}W_n^e$ : World price of intermediate imports
$P^d$ : Producer price of domestic good	$t$ : Export subsidy rate
$P^i$ : Consumer price of domestic good	$t_d^c$ : Tariff on consumption imports
$P_d^c$ : Price of consumption imports	$t_n^c$ : Tariff on intermediate imports
$P_n^c$ : Price of intermediate imports	$t^i$ : Indirect tax rate
$P_d^e$ : Value added price of exports	
$P_n^e$ : Value added price of D	

the version in the previous section, although for simplicity savings and investment have been eliminated, and the balance of trade is again assumed fixed. There are two major additions to the model. First is the introduction of separate production functions for exports and domestic goods (Equations 1 and 2), with the associated demand functions for capital, labor, and intermediate goods as inputs (Equations 7–12). For each factor equilibrium conditions are included (Equations 26–28) that embody an assumption of full employment of fixed aggregate stocks of capital and labor. Second is the distinction of two types of imports (each with its own tariff rate): consumption imports ( $M_d$ ), which combine with domestic output ( $D_d$ ) to provide the composite good ( $Q^c$ ), and intermediate imports ( $M_n$ ), which combine with domestic output ( $D_n$ ) to produce composite intermediate goods ( $N$ ) required to produce domestic and exported goods. The domestically produced and imported intermediate goods, as with consumption, are assumed to be imperfect substitutes, so the demand for each depends on its relative price and the elasticity of substitution (Equation 6)

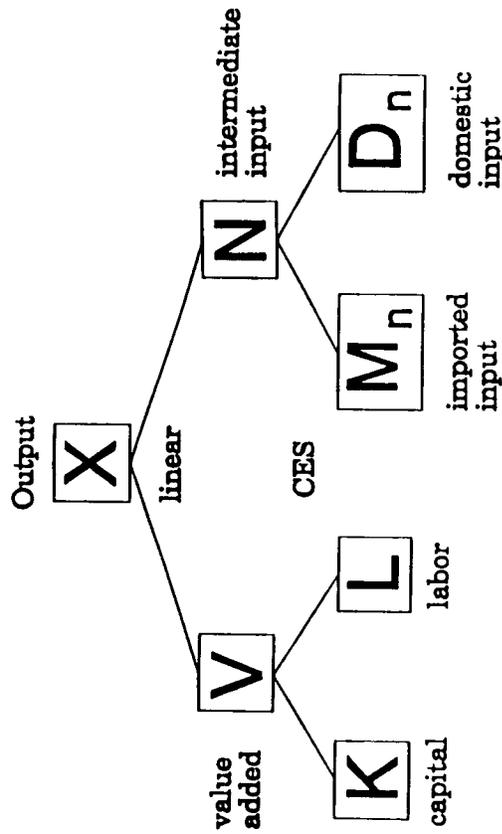


Figure 5. Sectoral production functions.

The resulting nested production structure in each sector is shown in Figure 5. At the top level, real value added and intermediate inputs are combined in fixed proportions to produce output. At the bottom level, there are two CES functions: one for labor and capital to produce real value added and one for imported and domestic intermediates to produce the composite intermediate input.<sup>24</sup> The use of fixed coefficients for the demand for composite intermediate input allows us to define a value-added or “net” price for each sector, shown in Equations 22 and 23.

To focus exclusively on the efficiency consequences of taxation, we assume, in the first instance, that all tax revenue is rebated to consumers in a lump-sum fashion, so that government spending appears as a component of total income in Equation 13. In addition, foreign capital inflows are also added to private income. We now use this model to explore the question: “Are uniform tariff rates optimal?”

The motivation for this question stems from the common view that differences among tariff rates introduce a distortion in the economy.<sup>25</sup> Different sectoral tariff rates imply that the relative domestic prices of

<sup>24</sup>The production function for real value added is often specified as a Cobb–Douglas function, which is a special case of the CES function with a substitution elasticity of one. When sectoral production functions are Cobb–Douglas, the resulting transformation function between  $D$  and  $E$  is approximately a CET function, as in the 1–2–3 model.

<sup>25</sup>See, for example, Harberger (1988), who argues in favor of uniform taxation.

Table 5: SAM for Stylized Numerical Model

	Expenditures				Rest of world			
	Activities		Factors					
	Export	Domestic	Final	Intermed		Labor	Capital	Consumer
Export ( $E$ )								30
Domestic ( $D$ )			73	2				
Final good ( $Q$ )								100
Intermediate	5							
( $N$ )								
Labor ( $L$ )	20	30						
Capital ( $K$ )	8	45						
Consumer			27	3	50	50		
Rest of world								
Total	30	75	100	5	50	50	100	30

two traded goods are not equal to their relative world prices. If world prices are viewed as the appropriate "shadow prices" of these traded goods, a varied tariff structure represents a distortion. However, if there are other distorting taxes in the economy, then the shadow prices of these traded goods in this second-best environment may not equal world prices.<sup>26</sup> In particular, if the domestic indirect tax structure is not optimal, the optimal tariff structure will generally not be uniform. We investigate this question by determining the optimal pattern of tariffs under various assumptions about the level of domestic indirect taxes. Introducing intermediate goods complicates the model sufficiently so that we cannot solve the model analytically. We proceed by computing numerical solutions to our optimization problem by using stylized data.<sup>27</sup>

Table 5 presents the base data for the numerical application. Real GDP equals 100 and the model economy exports and imports 30. The export sector ( $E$ ) is labor-intensive and uses domestic and imported intermediates. The domestic sector ( $D$ ) uses no intermediates. The balance of trade is zero and the single consumer thus demands 100 units of the composite consumer good ( $Q$ ). Since all prices and wages equal unity, the SAM indicates real as well as nominal magnitudes. The value-added production functions are assumed to be Cobb-

<sup>26</sup>Chambers (1989), Heady and Mitra (1987), and Dahl, Devarajan, and van Wijnbergen (1986) discuss the theoretical arguments.

<sup>27</sup>The model is solved with a nonlinear programming package called GAMS. See Brooks, Godwin, and McCombie (1988).

Douglas. The elasticity of substitution between imports and domestic goods ( $\sigma$ ) is equal to 2 for consumer goods and 0.5 for intermediate goods.

In the experiments, the government raises revenue with three tax instruments: tariffs on final and intermediate goods and an indirect tax on domestic sales. There is no export subsidy. The government is assumed to require total tax revenue of 15. The base data given in Table 5 represent a unique solution of the model with all tax rates set to zero. In the optimal tax experiments, choice is introduced by redefining the tax rates as variables. Optimal taxes are determined by maximizing  $Q$  subject to the equations of the CGE model plus the government revenue constraint. Alternative second-best scenarios are considered by also fixing one tax, the indirect tax on domestic goods ( $t^d$ ), and solving for optimal levels of tariff rates (the only remaining tax instruments).

The results are given in Table 6. The optimal pattern of tariffs is uniform only in the special case when the indirect tax is also set optimally.<sup>28</sup> When the indirect tax is below its optimal value, the second-best optimal tariff structure is to have a higher tariff on the final good than on the intermediate good. When the indirect tax is set at a level 15 percent below its optimum value, the best policy is to subsidize intermediate imports. The reverse is true when the indirect tax is above the optimum. In this case, the second-best optimum involves higher tariffs on imported final goods than on imported intermediates. In general, one would expect that domestic indirect taxes are too low rather than too high in developing countries. Thus, the appropriate policy rule of thumb is that tariff rates on intermediates should be lower than the rates for consumer goods.

Given the mistaken view that equal tariffs are best, it is often suggested that countries should at least move toward equal rates by raising the lowest tariffs and lowering the highest ones. In most developing countries, tariffs on intermediate goods are lower than those on final goods, which is consistent with our (second-best) rule of thumb. In this environment, moving toward equal rates would lower welfare.

Along with a highly variegated tariff structure, the second-best scenarios show smaller but significant variations in real variables. However, aggregate welfare varies little across the experiments. This result is consistent with results from a large number of empirical studies. Aggregate welfare gains from reducing price-wedge trade distortions

<sup>28</sup>In Table 2, the optimum indirect tax rate was determined by maximizing absorption ( $Q$ ) with all taxes, including  $t^d$ , as policy instruments. In the other experiments,  $t^d$  was fixed.



**Table 7:** Welfare Cost of Increasing Tax Revenue

Indirect tax rate (%)	Marginal welfare cost of increasing tax revenue as a % of additional revenue		Ratio (%) of constrained to second-best
	Constrained: equal tariffs	Second-best: differential tariffs	
15.4 (optimal)	0.0	0.0	
14.6 (-5%)	2.6	2.1	123.8
13.8 (-10%)	5.6	4.3	130.2
13.1 (-15%)	9.1	6.8	133.8

percent of the increased revenue. While smaller than rates of dead-weight loss found in the public finance literature, the loss is significant.<sup>30</sup> If policymakers mistakenly insist that tariff rates should be equal across sectors, they will design a tax system with a marginal efficiency cost a third higher than if they use optimal variegated tariffs.

Given the stylized nature of the model, these results are only suggestive. Nevertheless, they do point to the frail theoretical underpinning for the common policy rule of thumb that countries should unify their tariff structure. Furthermore, they show how a small model can capture the salient aspects of this important question and guide our intuition as we investigate it with more complex models. In fact, this particular issue has been investigated with larger applied models and the results from the two-sector model appear robust.<sup>31</sup>

## 5. CONCLUSION

This article shows how two-sector models can be used to derive policy lessons about adjustment in developing countries. Starting from a small, one-country, two-sector, three-good (1-2-3) model, we have shown how the effects of a foreign capital inflow and terms of trade shock can be analyzed. In particular, we derived the assumptions underlying the conventional policy recommendation of exchange rate depreciation in response to adverse shocks.

We next expanded the model to include savings, investment, and a

<sup>30</sup>One reason for the relatively small marginal welfare cost is that this model allows lump-sum transfers to households (equation 13), so the only efficiency loss comes from the price wedge.

<sup>31</sup>We thank Robinson and van Wijnbergen (1986) and Devarajan and Lewis (1989)

range of government policy instruments, including import tariffs, export subsidies, and indirect taxes. The introduction of government savings, and investment raises issues of macro closure. We discussed how the impact of policy interventions and exogenous shocks is sensitive to assumptions about how macro balance is achieved. We next extended the model to include factor markets and intermediate inputs. We used this extended model to explore issues of optimal tax policy. In particular, we asked whether uniform sectoral tariff rates, a common policy prescription for improving efficiency, are optimal. We showed that equating sectoral tariff rates is optimal only when other taxes are also set optimally. In second-best environments, a better rule of thumb would be to have a high tariff rate on consumer goods and a low rate on intermediates.

The models we have presented represent a stylized picture of how developing economies function. They are useful for qualitative analysis. However, policymakers are also concerned with the magnitude of the response to their initiatives. Furthermore, they require models that incorporate the more distinctive structural and institutional features of their economies. The lessons drawn from these models facilitate the interpretation of results from more complex applied models, because they are essentially multisectoral analogues of the small models developed here.

## REFERENCES

- Adelman, I., and Robinson, S. (1988) Macroeconomic Adjustment and Income Distribution: Alternative Models Applied to Two Economies. *Journal of Development Economics* 29: 1-22.
- Allston, J. M., Carter, C. A., Green, R., and Pick, D. (1989) Whither Armington Trade Models. *American Journal of Agricultural Economics*, forthcoming.
- Armington, P. (1969) A Theory of Demand for Products Distinguished by Place of Production. *IMF Staff Papers* 16: 159-176.
- Benjamin, N., and Devarajan, S. (1985) Oil Revenues and the Cameroonian Economy. In *The Political Economy of Cameroon* (I. W. Zartman and M. Schatzberg, Eds.). New York: Praeger Press.
- Benjamin, N., Devarajan, S., and Weiner, R. (1989) The "Dutch Disease" in a Developing Country: Oil Reserves in Cameroon. *Journal of Development Economics* 30 (1, January): 71-92.
- Brooke, A., Kendrick, D., and Meeraus, A. (1988) *GAMS: A User's Guide*. Redwood, CA: Scientific Press.
- Chambers, R. G. (1989) Tariff Reform and the Uniform Tariff. Preliminary draft, May.
- Dahl, H., Devarajan, S., and van Wijnbergen, S. (1986) Revenue-Neutral Tariff Reform: Theory and an Application to Cameroon. Discussion Paper No. 1986-25, Country Policy Department, The World Bank, May.
- de Janvry, A., and Sadoulet, E. (1987) Agricultural Price Policy in General Equilibrium Models: Results and Comparisons. *American Journal of Agricultural Economics* 69(2, May): 230-246.

- Dervis, K., de Melo, J., and Robinson, S. (1982) *General Equilibrium Models for Development Policy*. Cambridge: Cambridge University Press.
- Devarajan, S., and Lewis, J. D. (1989) Structural Adjustment and Economic Reform in Indonesia: Model-Based Policies versus Rules of Thumb. HIID Development Discussion Paper, Harvard University.
- Devarajan, S., Lewis, J. D., and Robinson, S. (1990) External Shocks and the Real Exchange Rate. Department of Agricultural and Resource Economics, University of California, Berkeley, processed.
- Devarajan, S., and de Melo, J. (1987) Adjustment with a Fixed Exchange Rate: Cameroon, Côte d'Ivoire, and Senegal. *World Bank Economic Review* 1(3): 447-487.
- Dewatripont, M., and Michel, G. (1987) On Closure Rules, Homogeneity, and Dynamics in Applied General Equilibrium Models. *Journal of Development Economics* 26(1, June): 65-76.
- Ginsburgh, V., and Robinson, R. (1984) Equilibrium and Prices in Multisector Models. In *Economic Structure and Performance* (M. Syrquin, L. Taylor, and L. Westphal, Eds.), New York: Academic Press.
- Ginsburgh, V., and Waelbroeck, J. (1981) *Activity Analysis and General Equilibrium Modelling*. Amsterdam: North-Holland.
- Hanson, K., Robinson, S., and Tokarick, S. (1989) United States Adjustment in the 1990's: A CGE Analysis of Alternative Trade Strategies. Working Paper No. 510, Department of Agricultural and Resource Economics, University of California, Berkeley.
- Harberger, A. (1988) Reflections on Uniform Taxation. Paper presented at the 44th Congress of the International Institute of Public Finance, Istanbul, August.
- Heady, C. J., and Mitra, P. K. (1987) Distributional and Resource Raising Arguments for Tariffs. *Journal of Development Economics* 20: 77-101.
- Melo, J. de, and Robinson, S. (1985) Product Differentiation and Trade Dependence of the Domestic Price System in Computable General Equilibrium Trade Models. In *International Trade and Exchange Rates in the Late Eighties* (T. Peeters, P. Praet, and P. Reding, Eds.), Amsterdam: North-Holland.
- Melo, J. de, and Robinson, S. (1989) Product Differentiation and the Treatment of Foreign Trade in Computable General Equilibrium Models of Small Economies. *Journal of International Economics* 27: 47-67.
- Powell, A. A. (1981) The Major Streams of Economy-wide Modelling: Is Rapprochement Possible? In *Large-Scale Macroeconomic Models* (J. Kmenta and J. B. Ramsey, Eds.), Amsterdam: North-Holland.
- Pyatt, G. and Round, J. T., Eds. (1985) *Social Accounting Matrices: A Basis for Planning*. Washington, DC: World Bank.
- Ratto, J. (1982) Different Macroclosures of the Original Johansen Model and Their Impact on Policy Evaluation. *Journal of Policy Modeling* 4(1): 85-97.
- Robinson, S. (1989a) Computable General Equilibrium Models of Developing Countries: Stretching the Neoclassical Paradigm. Working Paper No. 513, Department of Agricultural and Resource Economics, University of California, Berkeley.
- Robinson, S. (1989b) Multisectoral Models. In *Handbook of Development Economics* (H. B. Chenery and T. N. Srinivasan, Eds.), Amsterdam: North-Holland.
- Robinson, S. and Tyson, L. D. (1984) Modelling Structural Adjustment: Micro and Macro Elements in a General Equilibrium Framework. In *Applied General Equilibrium Analysis* (H. Scarf and J. B. Shoven, Eds.), Cambridge: Cambridge University Press.
- Salter W. (1959) Internal and External Balance: The Role of Price and Expenditure Effects. *Economic Record* 35: 226-238.
- Sen A. K. (1963) Neo-Classical and Neo-Keynesian Theories of Distribution. *Economic Record*

- Srinivasan, T. N., and Whalley, J., Eds. (1986) *General Equilibrium Trade Policy Modeling*. Cambridge, MA: MIT Press.
- Swan, T. (1960) Economic Control in a Dependent Economy. *Economic Record* 36: 51-66.
- Taylor, L. (1975) Theoretical Foundations and Technical Implications. In *Economy-wide Models and Development Planning* (C. R. Blitzer, P. B. Clark, and L. Taylor, Eds.), London: Oxford University Press.
- Taylor, L. (1983) *Structuralist Macroeconomics: Applicable Models for the Third World*. New York: Basic Books.