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Policy Lessons from a Simple Open-Economy Model

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This paper describes how to specify, solve, and draw policy lessons from small, two-sector, general equilibrium models of open economies.

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Summary findings

Devarajan, Go, Lewis, Robinson, and Sinko show how two-sector models can be used to derive policy lessons about adjustment in developing economies.

In the past two decades, changes in the external environment and in economic policies have been the key factors in the performance of developing economies. By and large the shocks have involved the external sector: terms-of-trade shocks or cutbacks in foreign capital. The policy responses most commonly proposed have targeted the external sector: depreciating the real exchange rate or reducing distortionary taxes to make the economy more competitive. The authors provide a starting point for analyzing the relation between external shocks and policy responses.

Starting from a small, one-country, two-sector, three-good (1-2-3) model, the authors outline how the effects of a foreign capital inflow and terms-of-trade shock can be analyzed. They derive the assumptions underlying the conventional policy recommendation of real exchange rate depreciation in response to adverse shocks. The implications of such trade and fiscal policy instruments as export subsidies, import tariffs, and domestic indirect taxes can also be studied in this framework.

The authors show that the standard advice to depreciate the real exchange rate in the wake of an adverse terms-of-trade shock rests on the condition that the income effect of the external shock dominates its substitution effect. But, depending on the characteristics of the economy (for example, the trade elasticities), policy results may run counter to received wisdom. For example, when the substitution effect of an adverse external shock dominates, real depreciation is inappropriate. An infusion of foreign capital does not necessarily benefit the nontradable sector, as the results of "Dutch disease" models suggest (for example, in the extreme case of nearly infinite substitution elasticity between imports and domestic goods). When import tariffs are significant sources of public revenue, potential revenue losses from tariff cuts must be offset by other revenue sources to maintain the external current account balance. The paper shows a simple way to calculate the necessary tax adjustment.

A major advantage of small models is their simplicity. The example in this paper can be solved analytically — either graphically or algebraically. It also can be solved numerically, using such widely available PC-based spreadsheet programs as Excel.* The numerical implementation involves only modest data requirements. The data that governments normally release on national income, fiscal, and balance of payments accounts are sufficient.

*A companion Excel-based model is available. Bank staff can copy the spreadsheet file "123.xls" from the Policy Research Department's network drive, prd@prdsvr01@worldbank, under the directory "models." The file can also be requested from the internet electronic mail address prdpe@worldbank.org. The file will be available on the Bank's Gopher in the future.

This paper — a product of the Public Economics Division, Policy Research Department — is part of a larger effort in the department to develop tools for analyzing tax policy. Copies of the paper are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact Carlina Jones, room N10-063, extension 37699 (38 pages). November 1994.

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Policy Lessons from A Simple, Open-Economy Model[1]

1. INTRODUCTION

This paper describes how to specify, solve, and draw policy lessons from small, two-sector, general equilibrium models of open, developing economies. 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; this paper provides a starting point for its analysis.

Two-sector models provide a good starting point because of the nature of the external shocks faced by these countries and the policy responses they elicit. 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 1973-74 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

[1] Forthcoming as a chapter in François and Reinert (1994). This paper is derived extensively from two previous ones: Devarajan, Lewis, and Robinson (1990) and Go and Sinko (1993).

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) reducing 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 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 will not be able to affect its international competitiveness since 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, the example presented in this paper can be solved analytically -- either graphically or algebraically. It also can be solved numerically by using the most widely-available, PC-based spreadsheet programs; hence, it is not necessary to learn a new, difficult programming language in order to get started. The presentation will introduce the approach used to solve larger, multisector models. Finally, these minimalist two-sector models behave in a similar fashion to more complex multisector models, so we can anticipate some of the results obtained from multisector models.

The plan of the paper is as follows. In Section 2, we present the simplest two-sector models. We specify the equations and discuss some modelling issues. We then analyze the impact of terms-of-trade shocks and changes in foreign capital inflows. In Section 3, we describe an easy way of implementing the framework and use it to discuss some policy issues. The conclusion, Section 4, draws together the main points of the paper.

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

Flows

(1) $\bar{X} = G(E, D^S; \Omega)$

(2) $Q^S = F(M, D^D; \sigma)$

(3) $Q^D = \dfrac{Y}{P^q}$

(4) $\dfrac{E}{D^S} = g_2(P^e, P^d)$

(5) $\dfrac{M}{D^D} = f_2(P^m, P^d)$

(6) $Y = P^x \cdot \bar{X} + R \cdot \bar{B}$

Prices

(7) $P^m = R \cdot pw^m$

(8) $P^e = R \cdot pw^e$

(9) $P^x = g_1(P^e, P^d)$

(10) $P^q = f_1(P^m, P^d)$

(11) $R \equiv 1$

Equilibrium Conditions

(12) $D^D - D^S = 0$

(13) $Q^D - Q^S = 0$

(14) $pw^m \cdot M - pw^e \cdot E = \bar{B}$

Identities

(i) $P^x \cdot \bar{X} \equiv P^e \cdot E + P^d \cdot D^S$

(ii) $P^q \cdot Q^S \equiv P^m \cdot M + P^d \cdot D^D$

(iii) $Y \equiv P^q \cdot Q^D$

Endogenous Variables

E: Export good
M: Import good
D^S: Supply of domestic good
D^D: Demand for domestic good
Q^S: Supply of composite good
Q^D: Demand for composite good
Y: Total income
P^e: Domestic price of export good
P^m: Domestic price of import good
P^d: Domestic price of domestic good
P^x: Price of aggregate output
P^q: Price of composite good
R: Exchange rate

Exogenous Variables

pw^e: World price of export good
pw^m: World price of import good
$\bar{B}$: Balance of trade
σ: Import substitution elasticity
Ω: Export transformation elasticity

2. 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 Ω. 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^x corresponds to the GDP deflator.

Equation 2 defines a composite commodity made up of D and M which 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 which has come to be called the Armington assumption.[2] Following this treatment, we assume the composite commodity is given by a

[2] See Armington (1969).

constant elasticity of substitution (CES) aggregation function of M and D, with substitution elasticity σ. Consumers maximize utility, which is equivalent to maximizing Q in this model, and equation 5 gives the desired ratio of M to D as a function of relative prices.[3] 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^q, corresponds to an aggregate consumer price or cost-of-living index.

Equation 6 determines household income. Equation 3 defines household 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 are linearly homogeneous, as are the corresponding dual price equations, 9 and 10. Equations 3 to 5 are homogeneous of degree zero in prices -- doubling all prices, for example, leaves real demand and the desired export and import ratios unchanged.[4] Since 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. models. Finally, these minimalist two-sector models behave in a similar fashion to more complex multisector models, so we can

[3] 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 directly.

[4] For the demand equation, one must show that nominal income doubles when all prices double, including the exchange rate. Tracing the elements in equation 6, it is easy to demonstrate that nominal income goes up proportionately with prices.

anticipate some of the results obtained from multisector models.

To prove that the three equilibrium conditions are not independent, it suffices to show that the model satisfies Walras' 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 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.[5] Multiplying equations 12 and 13 by their respective prices, the sum of equations 12, 13, and 14 equals zero as an identity (moving $\bar{B}$ 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.[6] 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 distinguishing "tradables" (including both imports and exports) and "nontradables." Their approach represented an advance and the papers started an active theoretical literature. However, they had little impact on empirical work. Even in an input-output table with over five hundred sectors, there are very few sectors

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[5] 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.

[6] 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).

which are purely non-traded; i.e., with no exports or imports. So defined, non-traded goods are a very small share of GDP; and, in models with 10-30 sectors, there would be at most only one or two non-traded sectors. Furthermore, the link between domestic and world prices in the Salter-Swan model does not depend on the trade share, only on whether or not the sector is tradable. If a good is tradable, regardless of how small is 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 non-tradables (or, better, as "semi-tradables"). The share of non-tradables 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, since exports, imports, and domestic goods in the same sector are all distinct.

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.[7] Note that it is equally important to specify imperfect transformability on the export side.

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[7] The CES formulation for the import-aggregation function has been criticized on econometric grounds (see Alston *et al.* (1990) for an example). It is certainly a restrictive form. For example, it constrains the income elasticity of demand for imports to be one 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 Tokarick (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 one in the U.S., results consistent with estimates from macroeconometric models. Factors other than relative prices appear to affect

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.[8]

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 single-country, trade-focused, computable general equilibrium (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 one, 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 non-tradables (D). Trade theory models (and our characterization in Table 1) often set R to one, with P^d then defining the real exchange rate. For other choices of numeraire, R is a monotonic function of the real exchange rate.[9]

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.[10] In this model, the shadow prices of the constraint equations correspond to market prices in the CGE model.[11] We will use the graphical apparatus to analyze the impact

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trade shares, and it is important to study what they might be and how they operate. Alston and Green (1990) also estimated the AIDS import formulation. A related paper is Shiells, Roland-Holst, and Reinert (1993).

[8] Dervis, de Melo, and Robinson (1982) specify a logistic export supply function in place of equation 4 in Table 1. Their logistic function is locally equivalent to the function that is derived from the CET specification.

[9] Dervis, de Melo, and Robinson (1982), Chapter 6, discuss this relationship in detail.

[10] Ginsburgh and Waelbroeck (1981) discuss, in detail, the general case where a multi-consumer 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.

[11] In the programming model, we implicitly choose Q as the numeraire good, with $P^q = 1$. In the graphical analysis, we set $R = 1$.

of two shocks: an increase in foreign capital inflow and a change in the international terms of trade.[12] We will also use this programming-model formulation, including endogenous prices and tax instruments, to derive optimal policy rules under second-best conditions.

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

Maximize $Q = F(M, D^D; \sigma)$ (absorption)

with respect to: M, E, D^D, D^S

subject to:

		Shadow Price
(1) $G(E, D^S; \Omega) \le \bar{X}$	(technology)	$\lambda^x = P^x/P^q$
(2) $pw^m \cdot M \le pw^e \cdot E + \bar{B}$	(balance of trade)	$\lambda^b = R/P^q$
(3) $D^D \le D^S$	(domestic supply and demand)	$\lambda^d = P^d/P^q$

The transformation function (equation 1 in Table 1 and constraint 1 in Table 2) can be depicted in the fourth (south-east) quadrant of the four-quadrant diagram in Figure 1. For any given price ratio P^d/P^e, 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 $\bar{B}$ is zero. Then, constraint 2, 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 one, then the slope of the line is one. For a given level of E produced, the balance-of-trade constraint determines how much of the imported good the country can buy. Intuitively, with no capital inflows ($\bar{B} = 0$), 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

[12] The discussion follows de Melo and Robinson (1989).

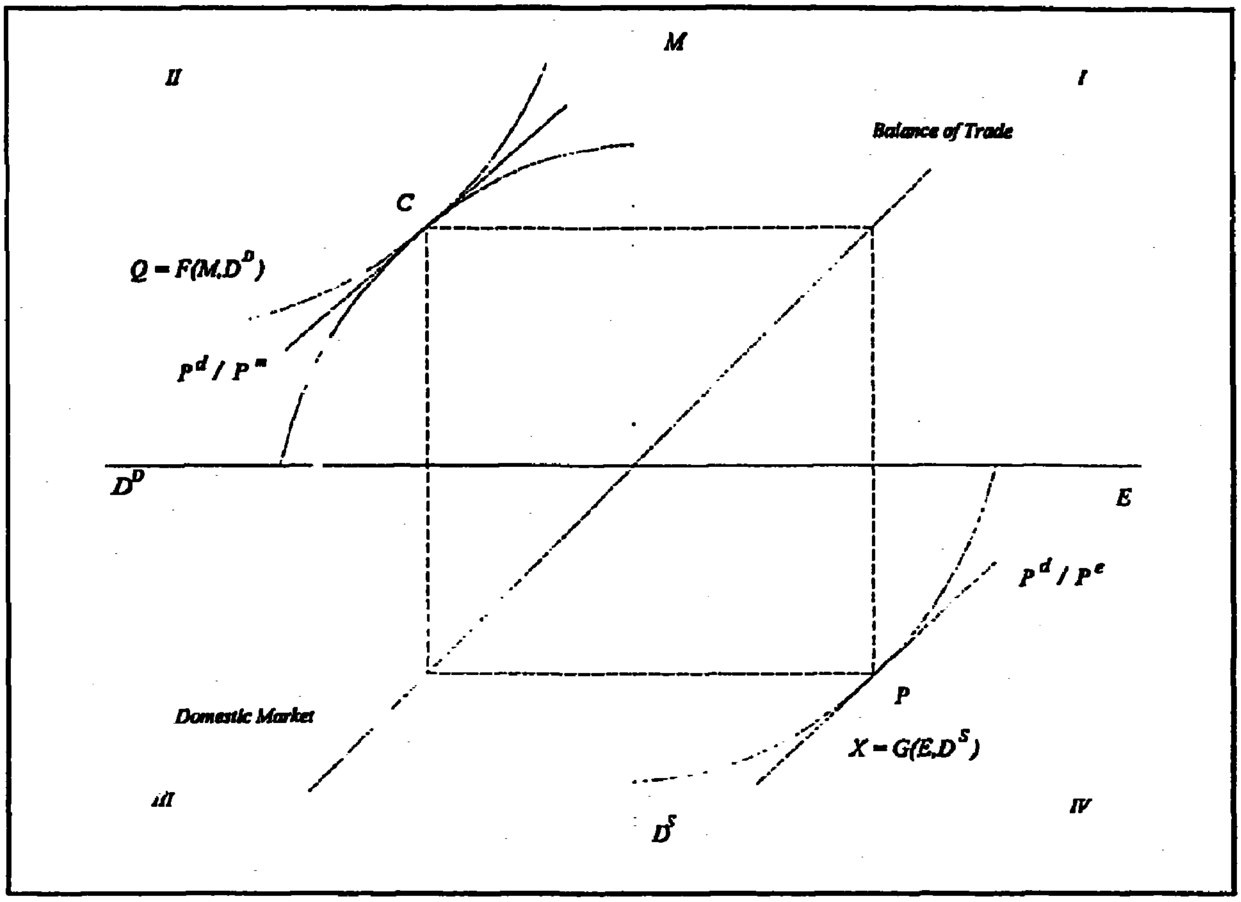

Figure 1: The 1-2-3 Programming Model

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 $\bar{B} > 0$). For example, the country gains additional access to world capital markets or receives some foreign aid. Alternatively, there is a primary resource boom in a country where the resource is effectively an enclave, so that the only direct effect is the repatriation of export earnings.[13] In all of these cases, we would expect domestic prices to rise relative to world prices and the tradable sector to contract relative to the nontradable sector. In short, the country would contract "Dutch disease."

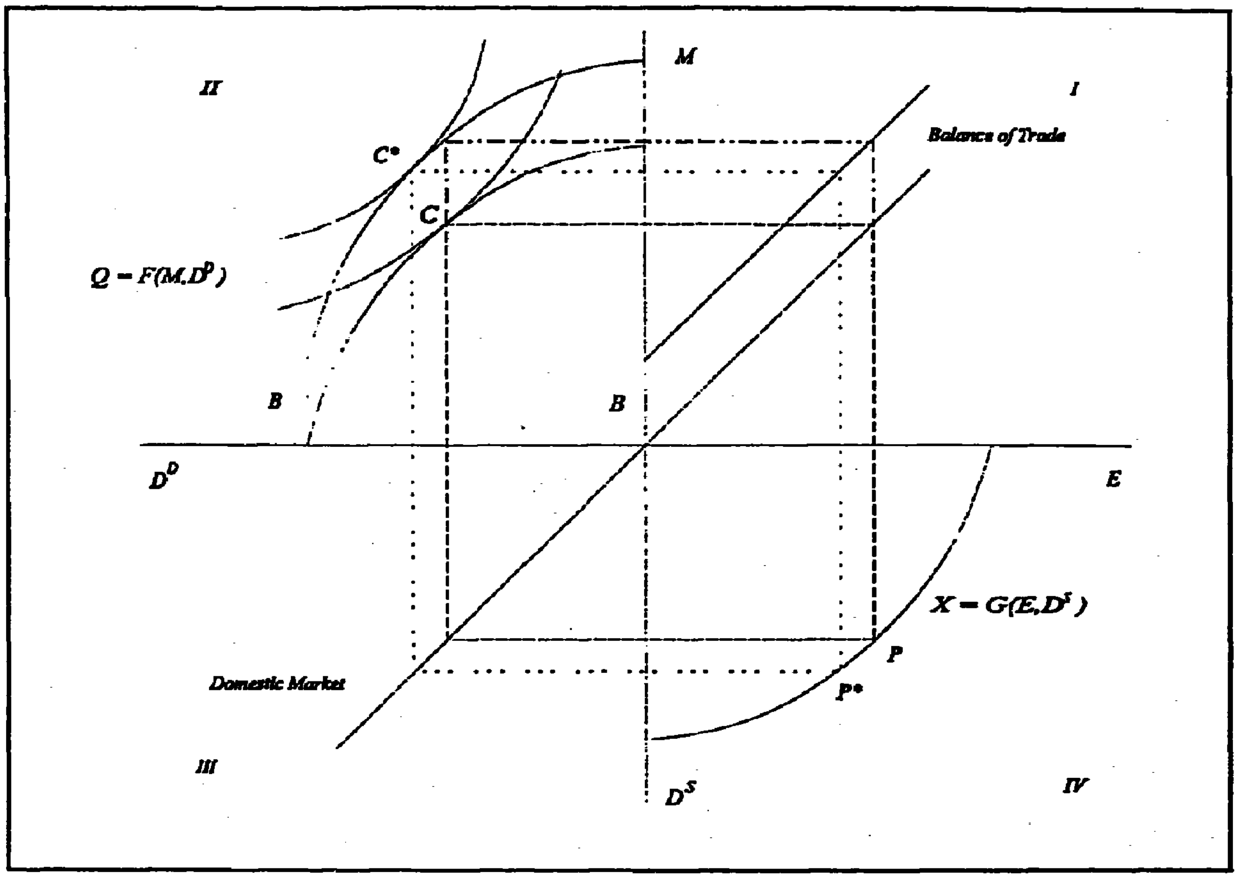

Figure 2: Increase in Foreign Capital Inflow

That this is indeed the case can be seen by examining Figure 2. The direct effect is to shift the balance of trade line up by $\bar{B}$. This shift, in turn, will shift the consumption possibility frontier up vertically by the same $\bar{B}$. The new equilibrium point will depend on the nature of the import aggregation function (the consumer's utility function). In Figure 2, the consumption point moves from C to C*, with increased demand for both D and M and an increase in the price of the domestic good, P^d. On the production side, the relative price has shifted in favor of the domestic good and against the export -- an appreciation of the real exchange

[13] See Benjamin and Devarajan (1985) or Benjamin, Devarajan, and Weiner (1989).

rate.

Will the real exchange rate always appreciate? Consider two polar extremes, which bracket the range of possible equilibria. Suppose the elasticity of substitution between imports and domestic goods is nearly infinite, so that the indifference curves are almost flat. In this case, the new equilibrium will lie directly above the initial one (point C), since the two consumption possibility curves are vertically parallel. The amount of D consumed will not change and all the extra foreign exchange will go towards purchasing imports. By contrast, suppose the elasticity of substitution between M and D is zero, so the indifference curves are L-shaped. In this case (assuming homotheticity of the utility function), the new equilibrium will lie on a ray radiating from the origin and going through the initial equilibrium. In this new equilibrium, there is more of both D and M consumed, and the price ratio has risen. Since P^m is fixed by hypothesis, P^d must have increased -- a real appreciation. The two cases bound the range of possible outcomes. The real exchange rate will appreciate or, in the extreme case, stay unchanged. Production of D will either remain constant or rise and production of E, the tradable good in this economy, will either stay constant or decline. The range of intermediate possibilities describes the standard view of the Dutch disease.

Consider now an adverse terms of trade shock represented by an increase in the world price of the imported good. The results are shown in Figure 3. The direct effect is to move the balance of trade line, although this time it is a clockwise rotation rather than a translation (we assume that initially $\bar{B} = 0$). For the same amount of exports, the country can now buy fewer imports. The consumption possibility frontier is also rotated inward. The new consumption point is shown at C*, with less consumption of both imports and domestic goods. On the production side, the new equilibrium is P*. Exports have increased in order to generate foreign exchange to pay for more expensive imports, and P^e/P^d has also increased to attract resources away for D and into E. There has been a real depreciation of the exchange rate.

Will there always be a real depreciation when there is an adverse shock in the international terms of trade? Not necessarily. The characteristics of the new equilibrium depend crucially on the value of σ,

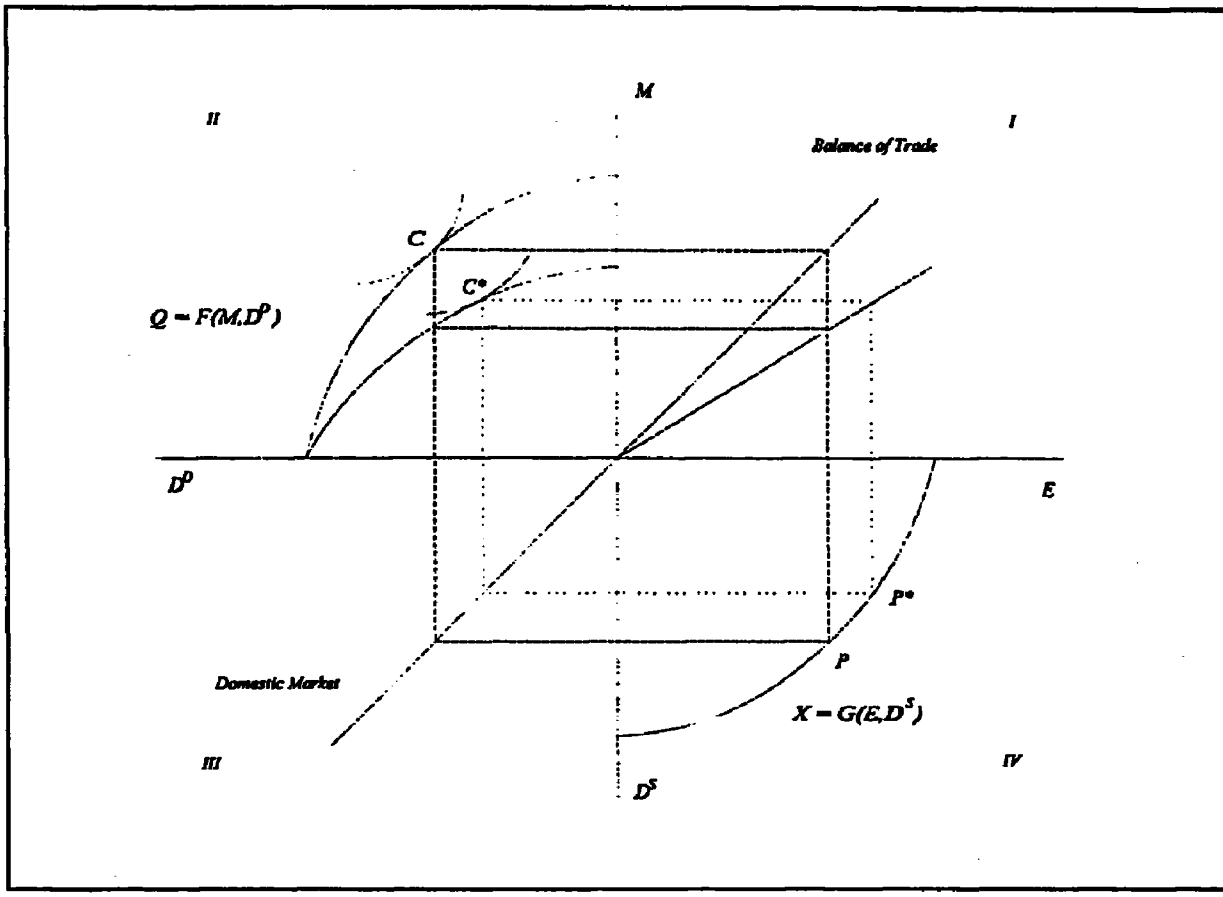

Figure 3: Change in World Prices

the elasticity of substitution between imports and domestic goods in the import aggregation function.

Consider the extremes of $\sigma = 0$ and $\sigma = \infty$. In the first case, as in Figure 3, there will be a reduction in the amount of domestic good produced (and consumed) and a depreciation of the real exchange rate. In the second case, however, flat indifference curves will have to be tangent to the new consumption possibility frontier to the left of the old consumption point (C), since 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.[14] 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

[14] We derive the result analytically below.

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, non-substitutable 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 non-critical) 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.[15]

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:

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

[15] 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 (1993).

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

$$\hat{M} + \hat{pw}^m = \hat{E}$$

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

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

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. Figure 4 illustrates the impact of a 10 percent import price shock on P^d under varying trade elasticities, $0 < \sigma < 2$ and $0 < \Omega < 2$. 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. 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.

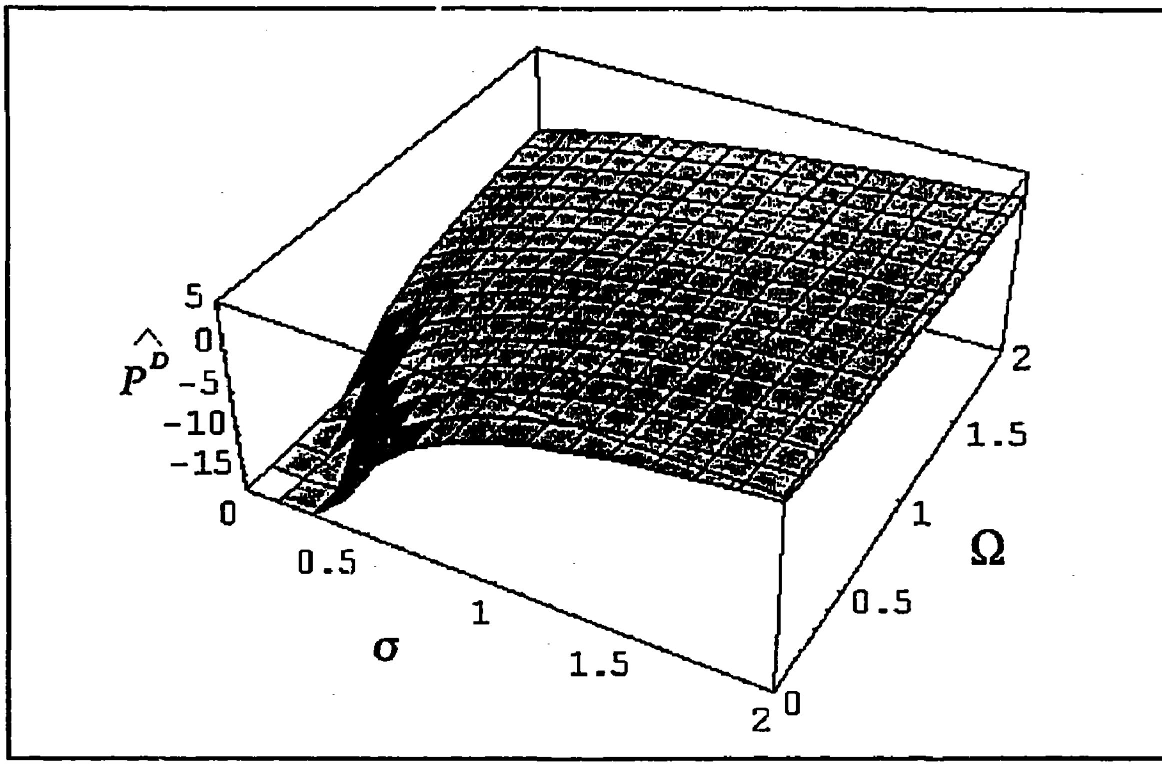

Figure 4: Import Price Shock, Trade Elasticities, and Domestic Prices

Of course, many aspects of the economy are left out of the small model. In particular, there is no government, factor markets, and intermediate goods; the framework is also static. Devarajan, Lewis, and Robinson (1990) discuss several extensions and modeling issues in a one-period setting; Devarajan and Go (1993) present a dynamic version of the 1-2-3 framework in which producer and consumer decisions are both intra- and intertemporally consistent. All these extensions require that the model be solved numerically. We turn therefore to the numerical implementation of the 1-2-3 model, extending the basic 1-2-3 model to include the government sector in order to look at policy intruments such as taxes.

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

Real Flows

(1) $\bar{X} = G(E, D^S; \Omega)$

(2) $Q^S = F(M, D^D; \sigma)$

(3) $Q^D = C + Z + \bar{G}$

(4) $E/D^S = g_2(P^e, P^d)$

(5) $M/D^D = f_2(P^m, P^t)$

Nominal Flows

(6) $T = t^m \cdot R \cdot pw^m \cdot M + t^s \cdot P^q \cdot Q^D + t^y \cdot Y - t^e \cdot R \cdot pw^e \cdot E$

(7) $Y = P^x \cdot \bar{X} + tr \cdot P^q + re \cdot R$

(8) $S = \bar{s} \cdot Y + R \cdot \bar{B} + S^g$

(9) $C \cdot P^t = (1 - \bar{s} - t^y) \cdot Y$

Prices

(10) $P^m = (1 + t^m) \cdot R \cdot pw^m$

(11) $P^e = (1 + t^e) \cdot R \cdot pw^e$

(12) $P^t = (1 + t^s) \cdot P^q$

(13) $P^x = g_1(P^e, P^d)$

(14) $P^q = f_1(P^m, P^t)$

(15) $R = 1$

Equilibrium Conditions

(16) $D^D - D^S = 0$

(17) $Q^D - Q^S = 0$

(18) $pw^m \cdot M - pw^e \cdot E - ft - re = \bar{B}$

(19) $P^t \cdot Z - S = 0$

(20) $T - P^q \cdot \bar{G} - tr \cdot P^q - ft \cdot R - S^g = 0$

Accounting Identities

(i) $P^x \cdot \bar{X} \equiv P^e \cdot E + P^d \cdot D^S$

(ii) $P^q \cdot Q^S \equiv P^m \cdot M + P^t \cdot D^D$

Endogenous Variables:

E: Export good
M: Import good
D^S: Supply of domestic good
D^D: Demand for domestic good
Q^S: Supply of composite good
Q^D: Demand for composite good
P^e: Domestic price of export good
P^m: Domestic price of import good
P^d: Producer price of domestic good
P^t: Sales price of composite good
P^x: Price of aggregate output
P^q: Price of composite good
R: Exchange rate
T: Tax revenue
S^g: Government savings
Y: Total income
C: Aggregate consumption
S: Aggregate savings
Z: Aggregate real investment

Exogenous Variables:

pw^m: World price of import good
pw^e: World price of export good
t^m: Tariff rate
t^e: Export subsidy rate
t^s: sales/excise/value-added tax rate
t^y: direct tax rate
tr: government transfers
ft: foreign transfers to government
re: foreign remittances to private sector
$\bar{s}$: Average savings rate
$\bar{X}$: Aggregate output
$\bar{G}$: Real government demand
$\bar{B}$: Balance of trade
Ω: Export transformation elasticity
σ: Import substitution elasticity

Table 4: List of Parameters and Variables in the Excel-Based 1-2-3 Model

	A	B	C	D	E	F	G	H	I
3									
4	Parameters		Exogenous Variables	Base Year	Current	Endogenous Variables	Base Year	Current	Cur/Base
5									
6	Elasticity for CET (st)	0.60	World Price of Imports (wm)	0.89	0.89	Export Good (E)	0.33	0.33	1.00
7	Elasticity for CES/Q (sq)	0.60	World Price of Exports (we)	1.01	1.01	Import Good (M)	0.50	0.50	1.00
8						Supply of Domestic Good (Ds)	0.67	0.67	1.00
9	Scale for CET (at)	2.22	Import Tariffs (tm)	0.13	0.13	Demand of Domestic Good (Dd)	0.67	0.67	1.00
10	Share for CET (bt)	0.77	Export Duties (te)	0.01	0.01	Supply of Composite Good (Qs)	1.18	1.18	1.00
11	Rho for CET (rt)	2.67	Indirect Taxes (ts)	0.08	0.08	Demand of Composite Good (Qd)	1.18	1.18	1.00
12			Direct Taxes (ty)	0.03	0.03				
13	Scale for CES/Q (aq)	1.97				Tax Revenue (TAX)	0.20	0.40	2.00
14	Share for CES/Q (bq)	0.38	Savings rate (sy)	0.17	0.17	Total Income (Y)	1.13	2.26	2.00
15	Rho for CES/Q (rq)	0.67	Govt. Consumption (G)	0.10	0.10	Aggregate Savings (S)	0.27	0.53	2.00
16			Govt. Transfers (tr)	0.12	0.12	Consumption (Cn)	0.83	0.83	1.00
17			Foreign Grants (ft)	0.02	0.02				
18			Net Priv Remittances (re)	0.01	0.01	Import Price (Pm)	1.00	2.00	2.00
19			Foreign Saving (B)	0.08	0.08	Export Price (Pe)	1.00	2.00	2.00
20			Output (X)	1.00	1.00	Sales Price (Pt)	1.08	2.17	2.00
21						Price of Supply (Pq)	1.00	2.00	2.00
22						Price of Output (Px)	1.00	2.00	2.00
23						Price of Dom. Good (Pd)	1.00	2.00	1.00
24						Exchange Rate (Er)	1.00	2.00	2.00
25									
26						Investment (Z)	0.25	0.25	1.00
27						Government Savings (Sg)	-0.01	-0.02	1.00
28						Walras Law (Z-S)	0.00	0.00	
29									

Table 5: List of Equations in the Excel-Based 1-2-3 Model

	J	K	L
3			
4	Eq.#	**Equations**	
5		*Real Flows*	
6	1	CET Transformation (CETEQ)	=at*(bt*E^(rt)+(1-bt)*Ds^(rt))^(1/rt)
7	2	Supply of Goods (ARMG)	=aq*(bq*M^(-rq)+(1-bq)*Dd^(-rq))^(-1/rq)
8	3	Domestic Demand (DEM)	=Cn+Z+G
9	4	E/D Ratio (EDRAT)	=((Pe/Pd)/(bt/(1-bt)))^(1/(rt-1))
10	5	M/D Ratio (MDRAT)	=((Pd/Pm)*(bq/(1-bq)))^(1/(1+rq))
11		*Nominal Flows*	
12	6	Revenue Equation (TAXEQ)	= tm*wm*Er*M + te*Pe*E + ts*Pq*Qd + ty*Y
13	7	Total Income Equation (INC)	= Px*X+ tr*Pq + re*Er
14	8	Savings Equation (SAV)	=sy*Y+Er*B+Sg
15	9	Consumption Function (CONS)	=Y*(1-ty-sy)/Pt
16		*Prices*	
17	10	Import Price Equation (PMEQ)	=Er*wm*(1+tm)
18	11	Export Price Equation (PEEQ)	=Er*we/(1+te)
19	12	Sales Price Equation (PTEQ)	=Pq*(1+ts)
20	13	Output Price Equation (PXEQ)	=(Pe*E+Pd*Ds)/X
21	14	Supply Price Equation (PQEQ)	=(Pm*M+Pd*Dd)/Qs
22	15	Numeraire (REQ)	=1
23		*Equilibrium Conditions*	
24	16	Domestic Good Market (DEQ)	=Dd - Ds
25	17	Composite Good Market (QEQ)	=Qd -Qs
26	18	Current Account Balance (CABAL)	=wm*M - we*E -ft - re
27	19	Government Budget (GBUD)	= Tax - G*Pt - tr*Pq + ft*Er
28			

3. NUMERICAL IMPLEMENTATION

As a means of evaluating economic policy or external shocks, general equilibrium analysis has several known advantages over the partial approach and its numerical implementation has become increasingly the preferred tool of investigation.[16] So far however, CGE models are cumbersome to build, requiring extensive data, model calibration, and the learning of a new and often difficult programming language. For that reason, the partial approach still dominates practical applications because of its simplicity. In the field of public finance, for example, it is a relatively simple affair for non-specialists to deal with tax ratios, the projections of collection rates of taxes and their corresponding bases, and, if necessary, to augment the analysis with estimations of tax elasticities.[17] Moreover, since only ratios of taxes to GDP are used, the partial approach has the further advantage of requiring the least information and offering a quick way of looking at the revenue significance of taxes. Nevertheless, using fixed ratios and assuming zero-elasticities ignores the feedback into other markets and the division of the tax burden; it limits the investigation and leads to an incomplete picture. General equilibrium analysis avoids these limitations but the problem has been to find an easy and convenient way of doing it.

Fortunately, the simplicity of the 1-2-3 model and the availability of more powerful Windows-based spreadsheet tools for the desktop PC, like *Microsoft Excel for Windows* (Excel hereafter),[18] provide appealing and tempting alternatives for CGE modeling. These tools have built-in graphics, easy integration with other *Windows* applications, and convenient access to interesting add-in programs. Being much easier to learn and use, they make CGE analysis more accessible to economists who are otherwise discouraged by unwieldy programming. A model based on a popular spreadsheet program can also become an effective vehicle for

[16] Robinson (1989) contains a survey of CGE applications to developing countries.

[17] See A. Prest (1962) and R. Chelliah and S. Chand (1974) for a discussion of such an approach.

[18] *Microsoft Excel and Windows* are trademarks of Microsoft Corporation.

illustrative and educational purposes. While Excel is one example and hardly the only software suitable for economic modeling, the robustness and flexibility of its solver function, which is quite capable of finding numerical solutions of systems of linear and non-linear equations and inequalities, as well as its userfriendliness and wide distribution make it a particularly attractive tool for potential CGE modelers.

In what follows, we describe a stepwise procedure to implement the 1-2-3 model using Excel.[19] We also run a few policy simulations by applying the model to one small open economy, Sri Lanka.

3.1 The 1-2-3 Model with Government and Investment

In the previous section, the discussion of the 1-2-3 model focused on the relative price of traded goods relative to the price of domestic goods and how this real exchange rate adjusts in response to exogenous shocks. In order to apply the framework to a particular country however, it has to be modified to fit real data and to handle policy issues. For example, the real exchange rate is not an instrument which the government directly controls. Rather, most governments use taxes and subsidies as well as expenditure policy to adjust their economies. Nor did the previous section touch on the equality of savings and investment which is important in bringing about macroeconomic balance or equilibrium. Table 3 presents an extended version of the 1-2-3 model to include government revenue and expenditure and also savings and investment. We make sure that the modifications introduced will conform to data that are commonly available (see calibration below.) In the new set-up, four tax instruments are included: an import tariff t^m, an export subsidy t^e, an indirect tax on domestic sales t^s, and a direct tax rate t^y. In addition, savings and investment are included. The single household saves a fixed fraction of its income. Public savings (budgetary deficit or surplus) is the balance of tax revenue plus foreign grants and government expenditures (all exogenous) such as government consumption and transfers to households. The current account balance,

[19] The discussion of Excel procedures is compatible with latest release, version 5. We also include in the footnotes, where applicable, how to implement the same procedures in the previous version of Excel.

taken to represent foreign savings, is the residual of imports less exports at world prices, adjusted for grants and remittances from abroad. Output is fixed for reasons cited in section 2. Foreign savings is also presently fixed, so that the model is savings-driven; aggregate investment adjusts to aggregate savings.[20] In sum, we have 20 equations and 19 endogenous variables. By Walras' law however, one of the equations, say the savings-investment identity, is implied by the others and may be dropped.

3.2 Defining Model Components

Building the 1-2-3 framework in Excel requires the usual modeling steps: (1) declaration of parameters and variables; (2) data entry; (3) assignment of initial values to variables and parameters; and (4) specification of equations. In addition, the model has to be precisely defined as a collection of equations; in some cases, it may require an objective function to be optimized. Finally, the solver is called to conduct numerical simulations.

A suitable way to arrange the 1-2-3 Model in an Excel worksheet is to assign separate columns or blocks for parameters, variables and equations. Separate columns are assigned for the base year and simulation values of variables. Labels and explanations for parameters, variables, and equations are easily provided in the adjacent left column to improve readability. We also assign a block for the data set with both initial and calibrated values displayed. Thus, we are able to arrange all necessary ingredients conveniently on a single worksheet.

3.3 Variables and Parameters

Table 4 is an example of how to organize the parameters and variables in an Excel-based model. We separate out from the rest of the exogenous variables the parameters related to the trade elasticities; the

[20] In the alternative investment-driven closure, aggregate investment is fixed and savings adjust through foreign savings (endogenous). For a discussion of alternative macro-closures, see the original work of Sen (1963) or the surveys by Rattso (1982) and Robinson (1989).

trade elasticities are generally defined at the outset of an experiment and parameters such as the share and scale values of the CES and CET functions are calibrated just once for both the base case and the current simulation (see the calibration section below). Column A provides a brief description of each parameter and Column B lists the corresponding numerical value. The exogenous variables (described in Column C) specify the external or policy shocks introduced in a particular experiment - their magnitudes are defined in Column E while their base-year values are presented in Column D. Likewise, the endogenous variables are listed in Column F to I. New values are computed for the endogenous variables during a simulation and entered in Column H as *Current*. Column I, *Cur/Base*, provides simple indices of change of the endogenous variables.

A useful feature in Excel is the capability to define names for various model parts. This is done by using the *Name* command and *Define* option under the *Insert* menu.[21] The cell in *B6* of Table 4, for example, can be called by its parameter name, *st*; hence, we can refer to parameters, variables, or equations by using their defined or algebraic names instead of cell locations. By doing this, we make the model specifications easier to read and mistakes easier to detect. To keep track of these names, it is advisable to write them out in explanation cells adjacent to the corresponding parameters, variables, and equations. In the example shown in Table 4, we write a short description and put in parenthesis the Excel label or name. Base year and current values of variables are distinguished using the normal convention -in the case of export good *E*, for example, the base year level is labelled as *E0* while *E* is retained for the simulated level.

3.4 Equations

The organization of the equations of our model is illustrated in Table 5. The equations are numbered and listed (in Column J of Table 5) in the same order as Table 3. Column K of Table 5 lists the equation descriptions and the Excel names in parentheses. The corresponding mathematical expressions are entered

[21] Prior to version 5 of Excel, this is done by using the *Define Name* command in the *Formula* menu.

in Column L. In the normal mode the formulas are hidden in the background and only the current numerical values are evident. The formulas are easily displayed by using the *Options* command on the *Tools* menu, selecting (or clicking) the *View* tab, and choosing *Formulas* in the *Window Options* box.[22]

In a spreadsheet like Excel, a formula is typically entered into a cell by writing out just the right-hand side of an equation as shown in Table 5. To complete the equation, each of these mathematical expressions has to be matched and set equal to a variable defined as above (see Solver section below).

The complicated expressions in Column L of Table 5 require some explanations. Equation 1 and 2, called *CETEQ* and *ARMG* in Excel, are the right-hand expressions of the CET and Armington (CES) functions in the 1-2-3 model, which usually take the following algebraic form:

$$Y = \bar{A}\left[\delta \cdot X_1^{\rho} + (1 - \delta) \cdot X_2^{\rho}\right]^{\frac{1}{\rho}}$$

where the CES substitution elasticity σ and CET transformation elasticity Ω are given by $\sigma = 1/(1 - \rho)$; $-\infty < \rho < +1$ in the CES case and $\Omega = 1/(\rho - 1)$; $1 < \rho < +\infty$ in the CET case. In the Excel implementation, the share parameter δ are labeled as *bt* or *bq*, the exponent ρ as *rt* or *rq*, and the elasticities as *st* or *sq*. Equation 4, *EDRAT*, is the right-hand side of the export supply function or the first order condition of the CET function:

$$\frac{E}{D} = \left[\frac{(1 - \delta_t) \cdot P^{e}}{\delta_t \cdot P^{d}}\right]^{\Omega}$$

[22] In earlier versions of Excel, the equations are easily unveiled by pulling down the *Options* menu and selecting *Formula* among the *Display* options.

while equation 5 (*MDRAT*) in Table 5 is the corresponding case (import demand function):

$$\frac{M}{D} = \left[\frac{\delta_q \cdot P^d}{(1 - \delta_q) \cdot P^m}\right]^{\sigma}$$

the dual price equations, equation 13 (*PXEQ*) and 14 (*PQEQ*), can take the following the form:

$$P = \bar{A}^{-1}\left[\delta^{1/(1-\rho)}\, P_1^{\rho/(\rho-1)} + (1 - \delta)^{1/(1-\rho)}\, P_2^{\rho/(1-\rho)}\right]^{\frac{\rho-1}{\rho}}$$

However, in practice, it is often convenient to replace the dual price equations with the expenditure identities, invoking Euler's theorem for linearly homogeneous functions:

$$P^x = \frac{P^e \cdot E + P^d \cdot D}{X}$$

$$P^q = \frac{P^m \cdot M + P^d \cdot D}{Q}$$

In the 1-2-3 model, the dual price equations embody the same information as the CET export transformation and CES import aggregation functions. In some applications, it is convenient to include the dual price equations, but drop the CET and CES functions.

3.5 Calibration

Another convenient feature of the 1-2-3 framework is its modest data requirements. Data from national income, fiscal, and balance-of-payments accounts, those normally released by national governments, are sufficient. To carry out the model, we used the 1991 data for Sri Lanka (Table 6). The original data were measured in billions of rupees. In the calibration, all data were scaled and indexed with respect to output, which is set to 1.00 in the base year (note Columns P and T).

Table 7 and 8 show the calibration of parameters and variables. The values of the parameters and variables are linked to the data in Table 6 so that model calibration is automatically done whenever the elasticities or base year data are changed. In Table 7, the calibration of the exponents, *rt* and *rq*, of the CET and CES functions (in Cells *B11* and *B15*) follows the discussion of the equations above. Given the base-year values of the exports *E0*, imports *M0*, and domestic good *Ds0* or *Dd0*, the share parameters *bt* and *bq* are calculated using the formulas in Cells *B10* and *B14*; these are derived from the input demand functions of CET and CES functions (see equation section above), respectively. The scale parameters *at* and *aq* are computed from the CET and CES functions directly in Cells *B9* and *B13*, respectively. An alternative procedure for calibration is to fix the variables and ask Excel to solve for parameter values that satisfy the base year equilibrium. Thus, one need not derive explicit formulas for the parameters, which is a useful property when dealing with more complicated functional forms.[23]

[23] However, calibration needs to be repeated every time that elasticities or base-year data are altered.

Table 6: Data in the Excel-Based 1-2-3 Model

	M	N	O	P	Q	R	S	T
3								
4		**Data - Sri Lanka, 1991**						
5			Rs Billion	Output=1			Rs Billion	Output=1
6		**National Accounts**			3	**Fiscal Account**		
7	1	Output (Value Added)	324.69	1.00		Revenue	76.18	0.23
8		Wages	163.32	0.50		NonTax	8.02	0.02
9						Current Expenditure	83.76	0.26
10		GDP at market prices	375.34	1.16		Goods & Services	35.58	0.11
11		Private Consumption	291.69	0.90		Interest Payments	22.07	0.07
12		Public Consumption	35.58	0.11		Transfers & Subsidies	26.10	0.08
13		Investment	86.38	0.27		Capital Expenditure	35.77	0.11
14		Exports	106.39	0.33		Fiscal Balance	-43.35	-0.13
15		Imports	144.7	0.45				
16								
17		**Tax Revenue**			4	**Balance of Payments**		
18	2	Sales & Excise Tax	32.03	0.10		Exports - Imports	-38.32	-0.12
19		Import Tariffs	18.62	0.06		Net Profits & Dividends	-0.78	0.00
20		Export Duties	1.14	0.00		Interest Payments	-8.82	-0.03
21		Payroll Tax	0.00	0.00		Net Private Transfers	11.60	0.04
22		Personal Income Tax	3.54	0.01		Net Official Transfers	7.90	0.02
23		Capital Income Tax	12.84	0.04		Current Account Balance	-28.42	-0.09
24		Total	68.16	0.21				
25						External Debt	260.50	0.80
26						Debt Service Payments	20.21	0.06
27								

Table 7: Calibration of Parameters in the Excel-Based 1-2-3 Model

	A	B
3		
4	**Parameters**	
5		
6	Elasticity for CET (st)	0.6
7	Elasticity for CES/Q (sq)	0.6
8		
9	Scale for CET (at)	=X0/(bt*E0^(rt)+(1-bt)*Ds0^(rt))^(1/rt)
10	Share for CET (bt)	=1/(1+(Pd0/Pe0)*(E0/Ds0)^(rt-1))
11	Rho for CET (rt)	=1/st + 1
12		
13	Scale for CES/Q (aq)	=Qs0/(bq*M0^(-rq)+(1-bq)*Dd0^(-rq))^(-1/rq)
14	Share for CES/Q (bq)	=((Pm0/Pd0)*(M0/Dd0)^(1+rq))/(1+ (Pm0/Pd0)*(M0/Dd0)^(1+rq))
15	Rho for CES/Q (rq)	= 1/sq -1
16		

Table 8: Calibration of Variables in the Excel-Based 1-2-3 Model

	C	D	E	F	G
3					
4	Exogenous Variables	Base Year	Current	Endogenous Variables	Base Year
5					
6	World Price of Imports (wm)	=Pm0/Er0/(1+tm0)	=wm0	Export Good (E)	=P14
7	World Price of Exports (we)	=Pe0*(1+te0)/Er0	=we0	Import Good (M)	=P15 + P19
8				Supply of Domestic Good (Ds)	=1-E0
9	Import Tariffs (tm)	=O19/O15	=tm0	Demand of Domestic Good (Dd)	=Ds0
10	Export Duties (te)	=O20/O14	=te0	Supply of Composite Good (Qs)	=M0 + Dd0
11	Indirect Taxes (ts)	=P18/Qs0	=ts0	Demand of Composite Good (Qd)	=Qs0
12	Direct Taxes (ty)	=SUM(P21,P23)/Y0	=ty0		
13				Tax Revenue (TAX)	=tm0*wm0*M0*Er0+te0*Pe0*E0+ts0*Pq0*Qd0+ty0*Y0
14	Savings rate (sy)	=(Y0 - Cn0*Pq0*(1+ts0) - ty*Y0)/Y0	=sy0	Total Income (Y)	= Px0*X0 + tr0*Pq0 + re0*Er0
15	Govt. Consumption (G)	=P12/(1 + ts0)/Pq0	=G0	Aggregate Savings (S)	=sy0*Y0 + Er0*B0 + Sg0
16	Govt. Transfers (tr)	=(T11 + T12-T8)/Pq0	=tr0	Consumption (Cn)	=P11/Pt0
17	Foreign Grants (ft)	=T22/Er0	=ft0		
18	Net Priv Remittances (re)	=SUM(T19:T21)/Er0	=re0	Import Price (Pm)	1
19	Foreign Saving (B)	=wm0*M0 - we0*E0 - ft0 - re0)/Er0	=B0	Export Price (Pe)	1
20	Output (X)	1	=X0	Sales Price (Pt)	=Pq0*(1+ts0)
21				Price of Supply (Pq)	1
22				Price of Output (Px)	1
23				Price of Dom. Good (Pd)	1
24				Exchange Rate (Er)	1
25					
26				Investment (Z)	=P13/Pt0
27				Government Savings (Sg)	= Tax0 - G0*Pt0 - tr0*Pq0 + ft0*Er0
28				Walras Law (Z-S)	=Z0*Pt0- S0
29					

3.6 Solving the Model

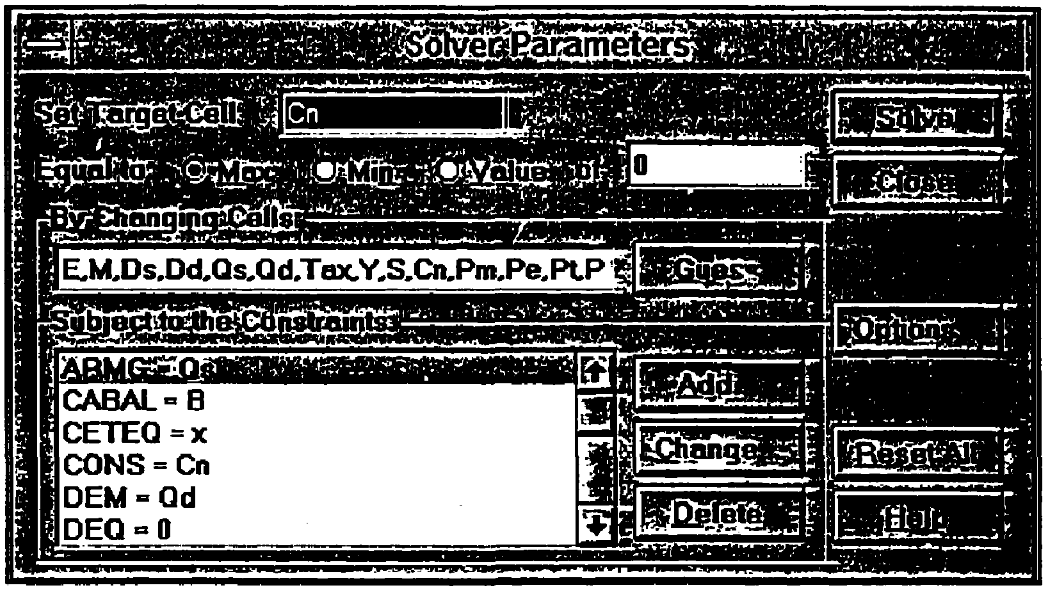

Illustration 1: Excel's Solver

Excel's solver is capable of solving a system of non-linear equations. The first step is to delineate parts of the worksheet that make up the model and specify the problem for Excel solver. This is done by selecting the *Solver* command from the *Tools* menu in Excel.[24] A *Solver Parameters* dialog box will appear on the screen (Illustration 1). Like in GAMS,[25] another numerical modeling software, Excel solves the model as an optimization or programming problem. In the *Set Target Cell* space, at the top of the dialog box, the name of the variable that is being maximized (max option) or minimized (min option) in the objective function may be entered. We select the consumption variable CN in this case but this has no effect in a CGE application since there will be as many variables and equations. The space may also be left empty. The 'optimal' solution is found *By Changing Cells,* where all the endogenous variables in the model are entered using their names or cell locations, and *Subject to the Constraints*, where all equations and non-negativity

[24] Prior to version 5, this is done by selecting the *Solver* command from the *Formula* menu in Excel

[25] GAMS stands for the General Algebraic Modeling System. See Brooke, Kendrick, and Meeraus (1988).

constraints of the model are listed. The *Add* option in the dialog box allows us to specify the equations and constraints one at a time. For example, the line highlighted in Illustration 1 matches the mathematical expression of the Armington function to total supply (ARMG=Q), which corresponds to the first equation of our model when arranged alphabetically.

The *Options* command in the *Solver Parameters* menu controls the solution process. The *Options* command lets one adjust the maximum iteration time and tolerance level as well as choose the appropriate search method. In the model, we used the Newton solution algorithm that proved out to be robust and fast. Average time for solving simulations with a 486/33 PC was around 10 seconds.

The model is run by choosing the *Solve* command. The solver starts iterating and the number of trial solutions appear in the lower left part of the worksheet. Once a solution that satisfies all the constraints has been found, the solver stops and displays a dialog box for showing the results. A variety of ways for reporting the outputs is possible. One can now choose between displaying the solution values on the worksheet or restoring the original values (initial guesses) of variables. Also, one may choose the option that produces both the original values and solution values. If there is no shock and the model is correctly calibrated, one should find a solution where all the variables equal their base year values within the fixed tolerance.[26] For example, 0.33, the base-year value of *E0* (export good) in Cell *G6* in Table 4, is entered as the initial guess or current value for the variable *E* in Cell *H6*. It is important to enter some feasible initial guesses for current values of variables before starting the solver. An empty cell is interpreted as zero, which is frequently an infeasible value for a variable.

[26] A good a way of testing the model is to maximize and minimize the objective variable, which should produce identical solutions in a general equilibrium framework.

3.7 Simulations

To test the model, we conduct two experiments. The first is a trivial case -- we double the nominal exchange rate, which is our numeraire. This is done by changing the right-hand side of equation 15 from 1.0 to 2.0 as shown in the cell L22 in Table 5. After the experiment is run, the results are shown as the current values of the variables in Column H of Table 4. As expected, all prices and incomes double while all quantities remain the same.

Next, we look at one important tax policy issue in developing countries - the fiscal/revenue implications of a tariff reform. Tariffs are a significant source of public revenue in many developing countries. In Sri Lanka, about 28 percent of tax revenue came from import duties in 1991. Therefore, the potential revenue losses of a tariff reduction in any attempt toward trade liberalization has to be offset by other revenue sources so as to prevent the balance of external payments from deteriorating.[27] In the experiment, we set the tariff collection rate to 0.05 (down from 0.13 in the base year) and ask by how much the domestic indirect taxes need to be raised to maintain the current account deficit from deteriorating, while keeping the same level of productive investment in the economy. To do this, we simply replace investment, *Z*, with the sales tax, *ts*, in the variable list and run the 1-2-3e model again. To attain the policy objective above, we find that sales and excise taxes need to be raised by about 33 percent (from the current rate of 0.08 to 0.11 in cells *G25* and *H25*, respectively, in Table 9). This figure of course depends, among others, on the degree of substitution possibilities between imports and domestic goods. Due to the 'automatic' calibration embedded in the worksheet, it would be straightforward to test the sensitivity of the results on alternate value of critical parameters by just entering new estimates to the corresponding cells.

[27] Greenaway and Milner (1991) and Mitra (1992) discuss the substitution of the domestic and trade taxes in greater details.

Table 9: Coordinated Tariff and Tax Reform

	F	G	H	I
3				
4	**Endogenous Variables**	Base Year	Current	Cur/Base
5				
6	Export Good (E)	0.33	0.33	1.02
7	Import Good (M)	0.50	0.51	1.01
8	Supply of Domestic Good (Ds)	0.67	0.67	0.99
9	Demand of Domestic Good (Dd)	0.67	0.67	0.99
10	Supply of Composite Good (Qs)	1.18	1.18	1.00
11	Demand of Composite Good (Qd)	1.18	1.18	1.00
12				
13	Tax Revenue (TAX)	0.20	0.19	0.95
14	Total Income (Y)	1.13	0.10	0.97
15	Aggregate Savings (S)	0.27	0.26	0.98
16	Consumption (Cn)	0.83	0.83	1.00
17				
18	Import Price (Pm)	1.00	0.93	0.93
19	Export Price (Pe)	1.00	1.00	1.00
20	Sales Price (Pt)	1.08	1.05	0.97
21	Price of Supply (Pq)	1.00	0.95	0.95
22	Price of Output (Px)	1.00	0.97	0.97
23	Price of Dom. Good (Pd)	1.00	0.96	0.96
24	Exchange Rate (Er)	1.00	1.00	1.00
25	Indirect Taxes (ts)	0.08	0.11	1.33
26	Investment (Z)	0.25	0.25	1.00
27	Government Savings (Sg)	-0.01	-0.01	1.10

4. CONCLUSION

This paper 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 show how the effects of a foreign capital inflow and terms-of-trade shock may be analyzed. In particular, we derive the assumptions underlying the conventional policy recommendation of exchange rate depreciation in response to adverse shocks.

We also implemented the model using a popular spreadsheet software, Excel, and by using widely available data. While Excel is not suitable for all type of tax or CGE models and certainly other programs, like GAMS, offer greater capability and indexing ease (e.g. over sectors or time), it is simple to use and a great way to get started. Add-in programs also extends its potential in new directions; for example, it is possible to add the element of uncertainty over critical parameters (e.g., trade elasticities) or exogenous shocks (e.g. the collapse of an export market like the CMEA trade) by performing risk analysis and Monte-Carlo simulations.[28]

The models in this paper present 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 this paper will facilitate the interpretation of results from more complex models, since these are essentially multisectoral analogues of the small models developed here.

[28] See, for example, Go (1994).

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