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Abstract

Two approaches are commonly used to determine the equilibrium real exchange rate in a country after external shocks: purchasing power parity (PPP) calculations and the Salter-Swan, tradables-nontradables model. There are theoretical and empirical problems with both approaches, and tensions between them. In this paper, we resolve these theoretical and empirical difficulties. We present a model which is a generalization of the Salter-Swan model that incorporates imperfect substitutes for both imports and exports. Within the framework of this model, there is a natural definition of the real exchange rate that is consistent both with the PPP approach and with the Salter-Swan model (suitably extended). Our model, however, is capable of capturing a richer set of phenomena, including terms-of-trade shocks and changes in foreign capital inflows, and also provides a practical way to estimate changes in the equilibrium real exchange rate, requiring little more information than that required to do PPP calculations. We also show that the results from our model are consistent with results from multisector computable general equilibrium (CGE) models, which generalize the trade specification of the small model.

I. INTRODUCTION

Faced with sharp increases in real interest rates, cutbacks in foreign lending, and deteriorating terms of trade — all of which lower the sustainable level of a country's current account balance — developing countries since the mid-1970s have been forced to reduce their trade deficits or, in some cases, to run surpluses. They have adopted "structural adjustment" programs, often with the assistance of the IMF or World Bank, aimed at facilitating the transition to lower current account deficits. A common ingredient in all these programs is a real devaluation of the exchange rate. A depreciated exchange rate, it is argued, will increase "competitiveness" of exports, make imports more expensive, and shift resources from sectors producing nontradables to those producing tradables.

Implicit in the recommendation of a devaluation is a view that the real exchange rate is out of equilibrium. By how much? What is the equilibrium exchange rate? Policymakers need answers to these questions to determine how large the exchange-rate adjustment must be and how large a shock the domestic price system must sustain. The most common approach in practice is to calculate the "purchasing power parity" (PPP) equilibrium exchange rate.[1] Following this approach, define the real PPP exchange rate as the ratio of the nominal exchange rate (R) multiplied by the ratio of an aggregate index of world prices (π) divided by an index of domestic prices (P):

$$R^{r} = R\frac{\pi}{P}$$

[1]Dornbusch (1987) presents a brief survey of the PPP theory of exchange rate determination and its critics.

The PPP approach is to find a prior benchmark year when the current account was in equilibrium at some "sustainable" level (perhaps, but not necessarily, zero). The real exchange rate for that year is assumed to be the desired equilibrium real rate for the post-shock period. The equilibrium nominal rate is then calculated by computing the inflation differential between the country and its trading partners since the benchmark year. Since $\hat{R}^r = 0$ by assumption, the required nominal rate of depreciation or appreciation is given by:

$$\hat{R} = \hat{P} - \hat{\pi}$$

where a hat over a variable indicates a rate of change. Note that R is defined as the price in domestic currency of a unit of foreign exchange. An increase in R denotes a depreciation of the exchange rate.

The PPP approach has been criticized on both theoretical and empirical grounds. An obvious problem is that the external environment and structure of the economy have likely changed since the last time the current account was in equilibrium. Consequently, the real exchange rate for the benchmark year will not be an equilibrium value in the post-shock period. Another strand of criticism has focused on the appropriate empirical definition of the real exchange rate. In neoclassical trade theory, the real exchange rate is defined as the relative price of tradable to nontradable goods. In the empirical application of the PPP approach, however, the usual practice is to measure P using an aggregate price index such as the GDP (gross domestic product) deflator and to measure π (world prices) using a similar aggregate index for the trading partners. One problem with this empirical practice is that the measure of P includes not only nontradables, but also tradables produced or bought by the country, while the measure of π includes not only tradables, but also nontradables produced by the trading partners.

An alternative approach is not to use standard aggregate price indices but instead to define separate indices for tradable and nontradable goods produced or sold in the country. Here the difficulty is with the definition of nontradables. Based on the Salter-Swan model of a small open economy, the proper definition of a nontradable sector is one in which there are neither exports nor competing imports.[2] Using this definintion, even looking at very disaggregated data, there are only a few non-traded sectors. Any resulting price index for nontraded goods reflects only a tiny share of GDP.

Furthermore, the Salter-Swan model does not distinguish between exports and imports. At the sectoral level, exportables and import substitutes are quite different. In developing countries, for example, exportables are usually primary goods or light manufactures while imports consist largely of intermediates and capital goods for which there are limited domestic substitutes. Aggregating these two types of goods into a single tradables sector will distort the view of how such a country adjusts, say, to a change in its international terms of trade.

In this paper, we present an approach to resolving these theoretical and empirical difficulties in defining the equilibrium real exchange rate (or ERER). We extend the Salter-Swan model to incorporate imperfect substitutes for both exports and imports, an approach we feel is especially realistic for developing countries. Both the PPP and Salter-Swan approaches will be shown to be special cases of this extended model, under restrictive assumptions. Also, the extended model provides a practical alternative to estimating changes in the equilibrium exchange rate that is both theoretically and empirically superior to the PPP approach.

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[2]See Salter (1959) and Swan (1960). In addition, a sector might be tradable even if there is no trade observed.

In section II, we present the extension of the Salter-Swan model. In section III, we derive the equilibrium real exchange rate for the model and show how it responds to changes in foreign capital inflows and the international terms of trade. We then discuss alternative approaches and present some illustrative calculations comparing how the different approaches measure changes in the equilibrium exchange rate.

II. A SINGLE-COUNTRY, TWO-ACTIVITY, THREE-COMMODITY MODEL

In a small economy in which all goods are traded, domestic relative commodity prices are completely determined by world prices (and the trade policy regime). In such a country, changes in the exchange rate have no effect on relative prices and hence on sectoral resource allocation. It is convenient and common in trade theory to work with analytic models that assume all goods are tradable. Disaggregated theoretical models in this tradition, however, are not well suited for the analysis of structural adjustment. In countries adjusting to external shocks, such as changes in foreign capital inflows or movements in world prices, the response of domestic relative prices to changes in the equilibrium exchange rate and trade policy are central to the analysis. In addition, empirical multisector models that start from the assumption that all goods are tradable tend to yield wildly unrealistic sectoral specialization in production and also greatly overstate the empirical response of domestic prices to external shocks.

As an alternative, consider a country which produces two goods, a non-traded domestic good D and an export E. The country also consumes two goods, D and an import M. The corresponding prices are P^d, P^e, and P^m. The country does not consume E. We will call this one-country, two-activity, three-commodity model the 1-2-3 model. The equations are set out in Table 1.

The D and E goods are assumed to be imperfect substitutes so that it is costly to change the allocation of goods between the domestic and export markets. The imperfect substitutability is captured by the economy's production possibility frontier, for convenience specified as a constant elasticity of transformation (CET) function [equation (1)].[3] Profit-maximization by producers, given the CET transformation frontier, yields the first-order conditions of equation (3). The relative supplies of D and E depend on their relative domestic prices, P^d and P^e, and on Ω, the elasticity of transformation.

The output of D is also assumed to be an imperfect substitute for imports in consumption, with a constant elasticity of substitution (CES) function [equation (2)]. The first-order condition for utility-maximizing consumers is given by equation (4), which defines the import demand function. The relative demands for M and D depend on their relative domestic prices, P^d and P^m, and on the elasticity of substitution, σ. In this model, the D sector is both the nontradable (as in the Salter-Swan model) and the import substitute.

Equations (5) and (6) define the domestic prices of the two traded goods. We take π^e and π^m, the world prices of exports and imports, to be fixed exogenously (the small-country assumption). The variable R is the nominal exchange rate and will serve as the numeraire price [equation (8)]. Finally, we impose a balance-of-trade constraint, equation (7). This states that the trade balance (written as imports minus exports) is fixed exogenously at $\bar{B}$.

[3] Alternatively, the D and E goods can be viewed as being produced by two different sectors that compete for the same factor which is in fixed supply. If the production functions of the two sectors are Cobb-Douglas, then the resulting production possibility frontier has a constant elasticity of transformation. Devarajan, Lewis, and Robinson (1990) provide a more complete discussion of the properties of the model, and its relationship to multisector models.

Table 1: The 1-2-3 Model

(1)	$\bar{X} = G(E, D; \Omega)$	Production possibility frontier
(2)	$Q = F(M, D; \sigma)$	Import aggregation function
(3)	$\frac{E}{D} = g(P^e, P^d; \Omega)$	Export supply function
(4)	$\frac{M}{D} = f(P^m, P^d; \sigma)$	Import demand function
(5)	$P^m = R \cdot \pi^m$	Domestic price of imports
(6)	$P^e = R \cdot \pi^e$	Domestic price of exports
(7)	$\pi^m \cdot M - \pi^e \cdot E = \bar{B}$	Balance of trade
(8)	$R \equiv 1$	Numeraire

Endogenous Variables
E = exports
M = imports
D = domestic good sold on domestic market
Q = composite good (absorption)
P^e = domestic price of exports
P^m = domestic price of imports
P^d = domestic price of domestic good
R = exchange rate

Exogenous Variables
$\bar{X}$ = aggregate output (or GDP)
π^e = world price of exports
π^m = world price of imports
$\bar{B}$ = balance of trade
Ω = elasticity of transformation in supply
σ = elasticity of substitution in demand

The system of equations (1) – (8) has eight unknowns: E, D, M, P^e, P^d, P^m, R and Q. Note that any solution to the system depends only on relative prices. The system is a general equilibrium model with two production activities (E and D) and three distinct goods (E, D, and M). We have implicitly introduced the equilibrium condition on the domestic market by using the same variable, D, for both supply [in equations (1) and (3)] and demand [equations (2) and (4))]. Furthermore, Walras' Law is satisfied since, by premultiplying (7) by R and adding $P^d \cdot D$ on both sides, we obtain:

$$P^e \cdot E + P^d \cdot D + R \cdot \bar{B} = P^m \cdot M + P^d \cdot D$$

which states that income equals expenditure.

III. THE ANALYTICS OF THE EQUILIBRIUM REAL EXCHANGE RATE

In the 1-2-3 model, assuming that (1) and (2) are CET and CES functions allows us to rewrite the first order conditions:

(9) $$\frac{M}{D} = k_1 \left[\frac{P^d}{P^m}\right]^{\sigma}$$

(10) $$\frac{E}{D} = k_2 \left[\frac{P^e}{P^d}\right]^{\Omega}$$

The various share parameters in the CES and CET functions have been gathered into the constant terms in equations (9) and (10).[4]

In addition, we rewrite the balance of trade equation, specifying B as a share of export earnings:

(11)
$$\pi^m \cdot M = \lambda \cdot \pi^e \cdot E$$

where

(12)
$$B = (\lambda - 1) \cdot \pi^e \cdot E = \pi^m \cdot M - \pi^e \cdot E$$

A zero trade balance corresponds to a λ of 1. This treatment is convenient when considering proportional changes, since the rate of growth of λ is well defined, even when B is initially zero. Note that when B is initially different from zero, a fixed λ does not correspond to a fixed B, since B will vary with the value of exports.

Log differentiation of equations (9) to (11) yields:[5]

(13)
$$\hat{M} - \hat{D} = \sigma \left(\hat{P}^{d} - \hat{P}^{m} \right)$$

(14)
$$\hat{E} - \hat{D} = \Omega \left(\hat{P}^{e} - \hat{P}^{d} \right)$$

(15)
$$\hat{\pi}^m + \hat{M} = \hat{\lambda} + \hat{\pi}^e + \hat{E}$$

Note that since R is the numeraire, $\hat{R} \equiv 0$, so that $\hat{P}^{m} = \hat{\pi}^m$ and $\hat{P}^{e} = \hat{\pi}^e$.

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[4]Alternatively, equations (9) and (10) can be seen as local approximations of arbitrary import demand and export supply functions. It is also feasible to use flexible functional forms. Hinojosa and Robinson (1991), for example, present a three-country trade model using the almost ideal demand system (AIDS) for the import aggregation functions, which include income as well as relative-price effects.

[5]Log differentiating: $d\log(X) = \hat{X} = dX/X$.

Unlike simple models with a single tradable good, this model recognizes that the incentive to consume imports versus domestic goods is different from the incentive to produce for exports versus the domestic market. In effect, there are two real exchange rates in this model. The first is the import or demand real exchange rate, $R^m = R \cdot \pi^m / P^d = P^m / P^d$, which captures the incentives to consume tradables versus nontradables. The second is the export or supply real exchange rate, $R^e = R \cdot \pi^e / P^d = P^e / P^d$, which captures the relative profitability of producing for the domestic or export markets. The 1-2-3 model thus extends the Salter-Swan model in distinguishing between two kinds of tradables, with separate demand and supply real exchange rates. With R as the numeraire price, the numerator in both measures is fixed by world prices. The only endogenous price in the model is P^d, which is common to both. Shocks which do not involve changes in world prices (such as a change in foreign capital inflow) will only affect P^d and hence will affect both real exchange rate measures identically.

Since P^d is the important relative price determining the real exchange rate, we want to solve for it in terms of $\hat{\pi}^m$, $\hat{\pi}^e$, and $\hat{\lambda}$. Subtract equation (14) from equation (13), and then substitute for $\hat{M} - \hat{E}$ in equation (15). A little manipulation yields:

$$(16) \qquad \hat{p}^d = \frac{1}{\sigma + \Omega} \left[(\sigma - 1) \cdot \hat{\pi}^m + (1 + \Omega) \cdot \hat{\pi}^e + \hat{\lambda} \right]$$

Equation (16) is the core result. It gives the equilibrium change in P^d for a given change in world prices or in foreign capital inflows, under the assumption that $\hat{R} = 0$. To facilitate comparison with the PPP approach, equation (16) can be rewritten with $\hat{R}$ included explicitly. Rearranging terms, define the equilibrium price level deflated (PLD) exchange rate:[6]

$$\underbrace{\hat{R} - \hat{P}^{d}}_{\text{PLD exchange rate}} = \underbrace{-\frac{(\sigma\cdot\hat{\pi}^{m} + \Omega\cdot\hat{\pi}^{e})}{\sigma + \Omega}}_{\text{World inflation}} + \underbrace{\frac{(\hat{\pi}^{m} - \hat{\pi}^{e})}{\sigma + \Omega}}_{\text{Terms of trade}} - \underbrace{\frac{\hat{\lambda}}{\sigma + \Omega}}_{\text{Balance of trade}} \tag{17}$$

The first term on the right, adjusts the equilibrium PLD exchange rate for world inflation, the second terms accounts for any change in the international terms of trade, and the third term accounts for any change in the sustainable balance of trade.[7]

Alternatively, rearranging Equation (17), one can define a real PPP exchange rate variable, R^r, whose rate of change, $\hat{R}^r$, equals the change in the nominal exchange rate ($\hat{R}$) minus the inflation differential between the home country and its trading partners. The change in the equilibrium real exchange rate is given by:

$$\hat{R}^{r} = \hat{R} - \underbrace{\left[\hat{P}^{d} - \frac{(\sigma\cdot\hat{\pi}^{m} + \Omega\cdot\hat{\pi}^{e})}{\sigma + \Omega}\right]}_{\text{Inflation differential}} = \underbrace{\frac{(\hat{\pi}^{m} - \hat{\pi}^{e})}{\sigma + \Omega}}_{\text{Terms of trade}} - \underbrace{\frac{\hat{\lambda}}{\sigma + \Omega}}_{\text{Balance of trade}} \tag{18}$$

The usual PPP approach seeks to correct for the first effect, differential inflation. In practice, the PPP approach ignores the second effect (the terms of trade) and handles the third by starting from a base in which the balance of trade is assumed to be in equilibrium (and hence $\hat{\lambda} = 0$). Equation (18) indicates that, in the 1-2-3 model, the equilibrium real PPP exchange

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[6]The PLD exchange rate is defined in Krueger (1978) and Bhagwati (1978), although we specify a particular choice of price index for deflating the nominal exchange rate.

[7]In this model, the sustainable level of foreign capital inflow is defined as a share of exports rather than as a fixed value. A common approach in the World Bank is to measure a country's creditworthiness by computing the ratio of debt service to export earnings.

rate will change only when there are changes in the international terms of trade or in the balance of trade. There is an apparent similarity between equation (18) and the standard PPP approach. The first term in brackets measures the differential between domestic and world-price inflation rates, measured by a weighted average of the growth rates of the world prices of imports and exports. The weights, however, are substitution and transformation elasticities, not trade shares, which are commonly used in defining world price indices.

In Equation (16), if $\hat{\pi}^m = \hat{\pi}^e = \hat{\pi}$ and $\hat{\lambda} = 0$, then $\hat{P}^d = \hat{\pi}^m = \hat{\pi}^e$. Alternatively, in equation (18), $\hat{R}^r = 0$ and $\hat{R} = \hat{P}^d - \hat{\pi}$. The equilibrium real exchange rate does not change and the equilibrium nominal exchange rate is adjusted for differential domestic and (uniform) foreign inflation rates. In this case, the usual purchasing-power-parity approach also works, provided that the domestic price index is P^d and the index of world prices contains only exportables and importables. With no terms of trade effect, the fact that the appropriate weights for defining the real exchange rate differ from the standard PPP approach does not matter. Put another way, at best, the PPP approach to computing changes in the equilibrium exchange rate is valid if and only if: (1) there is no change in the international terms of trade, and (2) there is no change in the equilibrium or "sustainable" level of foreign capital inflow.

As either σ or Ω approaches infinity, the model collapses to the standard small-country model with all goods tradable. In the limit, $\hat{P}^d = \hat{P}^m$ as σ approaches infinity and $\hat{P}^d = \hat{P}^e$ as Ω approaches infinity. In both cases, the real exchange rate is independent of the balance of trade, since the domestic price of the perfect substitute (either for exports or imports) is then determined by the exogenous world price. In such models, the exchange rate has no role in determining relative prices.

Consider now the impact of only a change in foreign capital inflow ($\hat{\lambda} \neq 0$, $\hat{\pi}^m = \hat{\pi}^e = 0$) with elasticities less than infinity. An increase in the balance of trade deficit ($\hat{\lambda} > 0$)

always generates a real appreciation ($\hat{P}^d > 0$ or, in equation (18), $\hat{R}^r < 0$). The model faithfully generates a "Dutch disease" scenario when the economy acquires a windfall increase in foreign exchange earnings.

Next, consider an increase in the world price of imports, which corresponds to a worsening in the international terms of trade facing the country ($\hat{\pi}^m > 0$, $\hat{\pi}^e = 0$, and $\hat{\lambda} = 0$). In this case, whether or not P^d rises or falls depends on the value of σ. If the elasticity of substitution is less than one, a typical case for developing countries, there is a fall in the equilibrium price of nontradables. As P^e/P^d rises, the country will shift resources into exports and away from nontradables in order to generate foreign exchange earnings to pay for the more expensive, crucial imports. Conversely, if σ is greater than one, then an increase in import prices generates an increase in the price of nontradables. In this case, perhaps more typical of developed countries, an increase in the price of imports leads to a diversion of resources away from exportables into the production of domestic substitutes for the imported goods.[8]

Finally, note that the response to changes in the world prices of exports and imports is asymmetric (unless $\sigma = \Omega$). The effect on P^d of a change in π^m is generally different from that arising from a change in π^e. However, the effect of a change in relative world prices on either the demand or supply real exchange rates (that is, on relative domestic prices) is the same, regardless of which world price changes. For example, consider the change in the supply real exchange rate, $R^e = P^e/P^d$. With a change in π^m and no change in π^e, the expression is given by equation (16), setting $\hat{\pi}^e = \hat{\lambda} = 0$:

[8]The volume of trade also falls. The effect of balance-of-trade and terms-of-trade shocks on the equilibrium real exchange rate in the 1-2-3 model have also been analyzed by de Melo and Robinson (1989). They derive an explicit expression for the country's offer curve, solving for quantity as well as price effects.

(19) $$\hat{R}^{e} = \hat{P}^{e} - \hat{P}^{d} = -\hat{P}^{d} = \frac{(1-\sigma)\cdot\hat{\pi}^{m}}{\sigma+\Omega}$$

With a change in $\hat{\pi}^e$ and no change in $\hat{\pi}^m$, manipulation of equation (16) yields:

(20) $$\hat{R}^{e} = \hat{P}^{e} - \hat{P}^{d} = \frac{(\sigma-1)\cdot\hat{\pi}^{e}}{\sigma+\Omega}$$

which is the negative of the earlier expression. When considering relative prices on the domestic market, Lerner symmetry is maintained.[9]

While there is no ambiguity with regard to changes in relative prices, the asymmetry of response does give rise to measurement problems in dealing with actual data. In practice, it is common to define a single real exchange rate using either some consumer price index or the GDP deflator, rather than an index of the price of domestically produced goods sold on the domestic market called for in equation (16). These alternative indices, however, include tradables. In the 1-2-3 model, the consumer price index corresponds to the price of Q, P^q, and the GDP deflator to the price of X, P^x. An index of P^q includes imports but excludes exports, while P^x includes exports but excludes imports. It is straightforward to construct an appropriate index for P^d based on national accounts data by removing export prices from the GDP deflator, using the expenditure identity:

(21) $$P^{x}\cdot X = P^{d}\cdot D + P^{e}\cdot E$$
$$P^{d} = \frac{P^{x} - S^{e}\cdot P^{e}}{1 - S^{e}}$$

where S^e is the export share in real GDP.

[9] Analogous expressions can be derived for the demand real exchange rate, $R^m = P^m/P^d$.

IV. ALTERNATIVE APPROACHES

In this section, we compare our proposed method for calculating the equilibrium exchange rate with other approaches, focusing on theoretical foundations and empirical tractability. Consider first the PPP approach, which is the most commonly used in practice and has the longest history.[10] The major problems with this method were discussed above. First, the PPP definition of an equilibrium real exchange rate holds only if there is no change in relative world prices and in the equilibrium level of foreign capital inflow. The 1-2-3 model, on the other hand, explicitly accounts for changes in the equilibrium real exchange rate due to changes in the balance of trade and in the international terms of trade.

Second, the PPP approach uses a single index of world prices as the numerator in the definition of the real exchange rate. Typically, some index of the overall inflation rate in a country's trading partners is used. Such an index will treat rises in export and import prices symmetrically. However, a country is not indifferent between an increase in its export price (a favorable terms-of-trade shock) and an increase in its import price (an unfavorable shock). Equation (16) takes this asymmetry into account.

In the same vein, in the 1-2-3 model, it is not the general level of prices in the trading partners that is relevant, but the world prices of a country's exports and imports. Harberger (1989) and others argue that one should use some broad index of trading-partner prices on the grounds of data availability; for example, consumer price indices are available for the major industrial countries on a monthly basis. However, these indices include prices of nontradables in the trading partners, as well as a different basket of imports, both of which

[10]Dornbusch (1987) traces its use back to 16th century Spain. For more recent arguments in its favor, see Balassa (1964), Bhagwati (1978), Krueger (1978), and Edwards (1989). Wood (1988) discusses a variety of real exchange rate measures and presents data on trends in developing countries.

are irrelevant for a country's own real exchange rate. Also, import and export price indices are generally available, so there is no need to look at data from trading partners. In addition, as noted above, the use of a consumer price index or GDP deflator to measure the domestic price of goods produced and consumed domestically (P^d) is both theoretically inappropriate and empirically unnecessary, since an index of P^d can be readily constructed from national accounts data.

A second approach to calculating the real exchange rate is based on the Salter-Swan model: compute a price index of tradables and divide by a price index of nontradables. While acknowledging the theoretical appeal of such an approach, both Harberger (1989) and Edwards (1989) recommend against it. Harberger claims that it "gives the wrong answer much of the time" (page 168) and discusses a number of cases in which he argues it is a bad approach. For one, he notes that, if all sectors with imports are labelled tradables, then an across-the-board import tariff will lead to a depreciation of the real exchange rate (since the domestic price of imports will rise relative to nontradables), whereas an export tax will cause the real exchange rate to appreciate. Harberger argues, based on Lerner symmetry, that import and export taxes should have symmetric effects on the real exchange rate, and so favors a looser empirical approach using broad-based price indices.

The 1-2-3 model resolves this theoretical dilemma. An import tariff will cause the demand real exchange rate (P^m/P^d) to depreciate and the supply real exchange rate (P^e/P^d) to appreciate. An export tax will have exactly the same effect since, as shown above, changes in domestic relative prices are the same regardless of whether a price shock hits exports or imports. More generally, by dividing the economy into three goods (E, D, and M) and assuming imperfect substitutability, we avoid the difficult classification and measurement problems implicit in forcing a dichotomy between tradables and nontradables. Domestic goods sold on the domestic market (D) play the dual role of nontradables and import substitutes. In multisector models, by varying σ across sectors, our treatment allows the specification of some goods as non-competitive or non-comparable with imports ($\sigma < 1$), while others are specified as close substitutes ($\sigma > 1$).

There is a third approach to calculating the real exchange rate which has been termed the "elasticities" approach.[11] Drawing on the analogy with the earlier elasticities approach to the balance of payments, it is argued that the real exchange rate should be related to the elasticities of demand for and supply of foreign exchange. Krueger *et al.* (1988) present a formula that is similar to equation (16), but is based on very different underlying theory. In the 1-2-3 model, the elasticities are parameters in the underlying structural import-demand and export-supply functions. The elasticities approach is based on a reduced-form equation with no underlying structural model specified. Such a reduced-form model may be consistent with a variety of structural models. For example, in their discussion, Krueger *et al.* (1988) assume that the entire nonagricultural sector consists of nontradable goods and services. Such an assumption, while convenient in their analysis, is at odds with the stylized facts characterizing most developing countries and is certainly not part of the structural underpinnings of the 1-2-3 model.

Mundlak, Cavallo, and Domenech (1990) employ a three-good model to look at the effects of macroeconomic policies on sectoral prices. The 1-2-3 model provides the general equilibrium model underlying their reduced form specification [see their equation (2)]. As in the 1-2-3 model, Mundlak *et al.* find it convenient to specify different supply and demand real exchange rates. They obtain the same result; namely, that the response of a terms of trade

[11]See, for example, Krueger, Shiff, and Valdez (1988); Mundlak, Cavallo, and Domenech (1990); and Dixit and Norman (1980). Magee (1973) discusses this approach from a macro perspective.

shock will be different on the supply and demand real exchange rates. Indeed, their response parameter (called ω in their article), which gives the response of the real exchange rate to a change in the price of imports, is equal to $(\sigma-1)/(\sigma+\Omega)$ in our notation. Our decomposition using equation (16) enables us to describe the precise conditions under which tariff liberalization will result in an appreciation of the real exchange rate — namely, that $\sigma < 1$. Mundlak *et al.* (p. 57) note only the possibility that the exchange rate will appreciate when there is a "low value of ω."

Furthermore, in the Mundlak *et al.* framework, all three goods are produced domestically. While they acknowledge that in Argentina "almost no domestically produced agricultural products are also imported" (p. 64), their framework makes it difficult for them to estimate the price of the home good. As they say, "... by the very fact that the home sector is not well defined, there are no direct observations on [its price])" (p. 64). As we have shown, the home sector is not only well-defined, but its aggregate price is obtainable from national accounts data.

Finally, trade-focused, multisector computable general equilibrium (CGE) models, which generalize the trade specification of the 1-2-3 model, have been used to analyze structural adjustment in developing countries.[12] A few studies used CGE models to explore the impact on the equilibrium exchange rate of various exogenous world-price shocks, changes in capital inflows, and domestic policy changes. The models serve as empirical laboratories for computing the decomposition presented in equation (18). The results from multisector CGE models of Turkey, Yugoslavia, and Hungary indicate that standard PPP calculations of the change in the equilibrium exchange rate can be badly off the mark,

[12]Many of these models were developed in the World Bank and start from the work of Dervis, de Melo, and Robinson (1982). See Robinson (1989) for a survey. Taylor (1990) surveys "structuralist" CGE models, which also largely share the trade specification of the 1-2-3 model.

greatly underestimating the required devaluation.[13] While supporting the arguments made in this paper, these studies represent major research efforts and do not offer a simple alternative to the PPP approach. The question is whether calculations of changes in the equilibrium exchange rate based on the 1-2-3 model, which require little more information than that required to do PPP calculations, provide a feasible alternative that significantly improves on the PPP approach.

V. ILLUSTRATIVE EMPIRICAL EXAMPLES

In this section, we illustrate our method of calculating the equilibrium real exchange rate (ERER) by applying the 1-2-3 model to two countries, Cameroon and Indonesia. Both are oil-producers and suffered a major terms of trade shock in 1986 when the world price of oil plummeted. We compute the ERER in light of this shock and compare it with what would have been obtained using the standard PPP approach. Of course, neither method represents the "true" ERER, since the 1-2-3 model is highly aggregated and the price shock hit only a few sectors in each country. To capture these sectoral effects, we also calculate the ERER using a multisector CGE model of each country. The CGE model has the virtue of providing a more disaggregated picture of the economy, at the cost of added data requirements and complexity. We then compare the calculations based on the 1-2-3 model with those from the CGE model. The comparison provides some indication of the extent of error introduced by using a highly aggregated model.

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[13]See, for example, Dervis and Robinson (1982) (Turkey); Lewis and Urata (1984) (Turkey); Robinson and Tyson (1985) (Yugoslavia); and Kis, Robinson, and Tyson (1990) (Hungary).

Cameroon

Cameroon is a member of the CFA Franc Zone, a monetary union of thirteen West and Central African countries and France.[14] One aspect of Zone membership is that Cameroon's nominal exchange rate is fixed (at 50 CFA Francs to the French Franc). A change in this parity requires the unanimous consent of the Zone members, which makes the nominal exchange rate virtually rigid. Hence, in discussing changes in the real exchange rate in Cameroon, we refer to changes in the domestic price level (P^d) and not to changes in the nominal exchange rate.

From 1982-86, Cameroon's international terms of trade deteriorated significantly: its average export price fell by 28 percent, while the average import price rose by 12 percent.[15] Most observers agreed that the country's real exchange rate in 1986 was out of equilibrium. But by how much? Consider, first, what the application of the PPP approach would have yielded. In 1982, Cameroon's resource balance (the balance of trade in goods and non-factor services) was zero. Thus, 1982 would be an appropriate choice for the benchmark year. Between 1982 and 1986, the domestic price level in Cameroon (represented by the GDP deflator) rose by 31 percent. The price level in France (represented by the French CPI) also rose by 31 percent during this period, and the exchange rate between the two countries was fixed.[16] In terms of domestic versus foreign inflation, Cameroon's real PPP exchange rate was evidently in equilibrium in 1986!

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[14]In fact, there are two monetary unions, one for the West and the other for the Central African states. The rules governing the two are almost identical, so the distinction is not relevant here.

[15] Unless otherwise indicated, all data in this sub-section are from World Bank (1990).

[16]International Monetary Fund (1989). Honohan (1990) shows that inflation in the CFA countries as a whole was not significantly different from French inflation from 1965-88.

Table 4: Changes in the Equilibrium Domestic Price Level in Cameroon, 1982-86

Ω (export transformation)	σ (import substitution elasticity) 0.25	0.50	0.75	1.00
0.25	-88.0	-54.7	-38.0	-28.0
0.50	-68.0	-48.0	-36.0	-28.0
0.60	-63.3	-46.2	-35.4	-28.0
0.75	-58.0	-44.0	-34.7	-28.0
1.00	-52.0	-41.3	-33.7	-28.0

Notes: Percent change in domestic prices, $\hat{P}^d$, due to a 12% change in import prices, $\hat{\pi}^m$, and a -28% change in export prices, $\hat{\pi}^e$. The nominal exchange rate and the balance of trade are assumed unchanged: $\hat{R} = 0$ and $\hat{\lambda} = 0$.

Even with no change in the balance of trade, the PPP calculation can be very misleading when there are changes in the international terms of trade. We can use the 1-2-3 model to estimate the change in the ERER, taking the relative price shock into account. We also assume that the only shock facing the country was the change in international prices. Table 2 shows the change in the domestic price level for different values of σ and Ω, given the actual changes in average export and import prices (–28 and +12 percent). The calculations use equation (16).

The equilibrium changes in the domestic price level range from –28 to –88 percent, depending on the elasticities. Estimates of values for σ and Ω for Cameroon, based on an average of sectoral estimates presented in Table 5 below, are 0.5 and 0.6, respectively. In this case, the required decline in the domestic price level is 46.2 percent. Using the decomposition in Equation (18), the equilibrium real devaluation is 36.4 percent — a far cry from the zero percent prescribed by the usual PPP approach. Assuming that $\hat{R} = 0$, 36.4 percentage points of the 46.2 percent required fall in domestic prices is attributable to the deterioration in the terms of trade (changes in relative international prices). The required adjustment for differential inflation based on world export and import prices (rather than on measures of general inflation for the trading partners) is 9.8 percentage points. Even using an appropriate PPP measure, the inflation differential accounts for only a small part (21% = 9.8/46.2) of the equilibrium change in the domestic price level.

Given that the terms-of-trade shock affects only a few sectors, is there significant aggregation bias in using such an aggregated model? How different would the results be if we used a more disaggregated multisector model? We explore this issue by simulating the terms of trade shock with an eleven-sector CGE model of Cameroon.[17] Table 2 describes the sector-specific world-price shocks which Cameroon faced. In the aggregate, they closely approximate the terms-of-trade shock we assumed for the 1-2-3 model. The table also provides trade data and the sectoral elasticities of import substitution and export transformation.

A simulation of the CGE model with the shocks described in Table 2 results in a decrease in the equilibrium domestic price level in Cameroon of 44.5 percent. The 1-2-3 model yielded a decrease of 46.2 percent. Of course, the disaggregated model provides a great deal more information, especially regarding the structural adjustment process at the sectoral level. However, the 1-2-3 model does an excellent job determining the equilibrium exchange rate.

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[17]The CGE model of Cameroon is described in detail in Benjamin, Devarajan, and Weiner (1989).

Table 5:Sectoral Shocks and Initial Trade Data, Cameroon CGE Model

Sector	Percent changes in world prices: Imports	Exports	Base year levels: (billions CFA francs) Imports	Exports	Elasticities σ and Ω
Food crops	—	—	11.1	5.5	1.50
Cash crops	—	-40.	11.8	232.5	0.90
Forestry	—	—	0.0	24.9	0.40
Food processing	—	—	22.9	15.8	1.25
Consumer goods	25.	—	37.2	12.4	1.25
Intermediate goods	20.	-50.	208.6	379.6	0.50
Cement	—	—	65.8	35.9	0.75
Capital goods	20.	—	448.9	20.6	0.40
Construction	—	—	0.0	0.0	0.00
Private services	—	—	245.6	222.2	0.40
Public services	—	—	0.0	0.0	0.00

Notes: Export and Import levels are in billions of 1985 CFA francs. Import substitution and export transformation elasticities are the same in each sector. A dash (—) indicates no change.

Indonesia

Indonesia has maintained an open system of foreign exchange for more than two decades. Despite a proliferation of regulations and controls on merchandise trade, it has avoided the imposition of any restrictions on international capital movements. For the period prior to 1986, Indonesia's nominal exchange rate was fixed against the dollar by the central bank, with periodic, often sizeable, devaluations engineered to correct for the cumulative drift since the previous major adjustment.

Until the late 1980s, Indonesia's export structure was dominated by oil. Indonesia benefitted tremendously from the OPEC-led price increases of 1973 and 1979-80, and succeeded (where many others failed) both in investing those resources in physical and human resource development and in fostering broad-based economic growth. The combination of plummeting oil prices and international currency realignment that began in late 1985 signalled an abrupt and painful end to the boom years. Not only did the price of oil drop from over $30 per barrel to as low as $10 within a few months, but also the weakening of the dollar against other currencies drastically raised the dollar servicing cost of Indonesia's debt (60 percent of which is in non-dollar currencies, including 40 percent denominated in yen).

Faced with a terms-of-trade shock of this magnitude, the exchange rate came under pressure. Clearly, some change was required. In late 1986, policymakers responded with a 45 percent devaluation against the dollar. In an effort to forestall the rate "creep" that had followed earlier adjustments, they concurrently adopted a more flexible policy that allowed for frequent (even daily) adjustments in the nominal exchange rate in order to preserve the "real" benefits of the devaluation and maintain adequate incentives for exports.

We evaluate the exchange rate adjustment using the various models presented above. Consider first the PPP approach, in which the appropriate adjustment depends only on the size of the inflation differential between Indonesia and the rest of the world. The first and most difficult task is to choose an appropriate benchmark. There is no year since 1974 when Indonesia's current account came close to being "balanced" (that is, equal to zero). During the period, it vacillated between a $2.2 billion surplus (1979/80) and a $7.0 billion deficit (1982/83).[18] An alternative is to define a "sustainable" deficit from a "normal" year, and base the PPP from that point. From this perspective, the best choice would seem to be 1984/85, when the deficit was around –$2.0 billion. In the two years between 1985/86 and

[18]All data are presented for Indonesian fiscal years, which run from April 1 to March 31. Thus, 1979/80 refers to April 1, 1979, to March 31, 1980, and is also called "fiscal year 1979."

1987/88, Indonesian prices (the CPI) changed by 18.6 percent, while the U.S. CPI changed by 7.0 percent. This would suggest a PPP nominal depreciation of 11.6 percent. Alternatively, the domestic price level will have to decline by 11.5 percent to restore the real exchange rate to its equilibrium value. To be sure, focusing only on dollar inflation seems incorrect, since Indonesia's major export market (and creditor) is Japan. To make a rough correction, we average U.S. and Japanese inflation over the period, which lowers "world" inflation to 4 percent, and consequently raises the PPP depreciation to 14.6 percent.

The PPP calculation does not reflect the sharp deterioration in the international terms of trade experienced during this period. To take this shock into account, we turn to the 1-2-3 model. As in the Cameroon example, we assume that the terms-of-trade shock was the only one facing the country. Moreover, for Indonesia, we focus only on the movement oil prices, ignoring movements in other international prices. For 1985 through 1987, available data suggest that Indonesia's average export prices fell by 13 percent (with oil prices dropping by 31 percent), while its average import price rose by 18 percent.[19]

Table 4 shows the change in the domestic price level ($\hat{P}^d$) for different values of the CET export and CES import elasticities, using the average price changes cited above and applying equation (16). The nominal exchange rate is assumed unchanged, while the balance of trade declines by 2.6 percent (measured by $\hat{\lambda}$). This table parallels Table 4 for Cameroon.

The equilibrium domestic price movements range from –65 to –14 percent, depending on the elasticities. The middle row and column (Ω = 0.57 and σ = 0.59) are reasonable elasticity values for Indonesia, and were obtained through a traded-weighted average of the sectoral elasticities presented in Table 8 below. With these parameter values, the domestic price is estimated to decline by 26 percent (assuming $\hat{R} = 0$). Of this 26 percent, 27 percent

[19]1985 data come from World Bank (1987), 1987 data from World Bank (1988).

is due to the terms-of-trade shock, 2 to the change in the trade balance, and –3 to the change in world prices.

Table 6: Equilibrium Domestic Price Changes in Indonesia, 1985-87

Ω (export transformation elasticity)	σ (import substitution elasticity) 0.25	0.50	0.59	0.75	1.00
0.25	-64.8%	-37.1%	-31.0%	-23.2%	-14.9%
0.50	-47.5%	-31.0%	-26.8%	-21.1%	-14.5%
0.57	-44.4%	-29.7%	-25.9%	-20.6%	-14.4%
0.75	-38.8%	-27.3%	-24.2%	-19.7%	-14.3%
1.00	-33.6%	-24.9%	-22.4%	-18.7%	-14.1%

Notes: Percent change in the domestic price, $\hat{P}^d$, due to a 18 percent increase in import prices and a 13 percent decrease in export prices. The nominal exchange rate is assumed unchanged, while the balance of trade declines by 2.6 percent ($\hat{\lambda}$).

To facilitate comparison of these results with the PPP model, Table 7 summarizes the real depreciation ($\hat{R}^r$) suggested by the 1-2-3 model, using the formulation of equation (18). Estimates of the real depreciation range from 17 to 68 percent. With average Indonesian elasticities, the 1-2-3 model requires depreciation of the real exchange rate of 29 percent, compared to the constant real rate based on the PPP approach. Of the 29 percent real devaluation, 27 percentage points are due to changes in the international terms of trade, while only 2 percentage points are due to the change in the balance of trade.

Table 7: Equilibrium Real Exchange Rate Depreciation in Indonesia, 1985-87

Ω (export transformation elasticity)	σ (import substitution elasticity) 0.25	0.50	0.59	0.75	1.00
0.25	67.7%	45.1%	40.2%	33.8%	27.1%
0.50	45.1%	33.8%	31.0%	27.1%	22.6%
0.57	41.1%	31.5%	29.0%	25.6%	21.5%
0.75	33.8%	27.1%	25.2%	22.6%	19.3%
1.00	27.1%	22.6%	21.3%	19.3%	16.9%

Notes: Percent change in the equilibrium real exchange rate, $\hat{R}^r$, due to a 18 percent increase in import prices, a 13 percent decrease in export prices, and a 2.6 percent decline in the balance of trade ($\hat{\lambda}$).

Finally, we address the question of how much our results have been affected by the use of an aggregated model. For this purpose, we examine this same terms-of-trade shock using an 18-sector CGE model of Indonesia.[20] Table 8 summarizes the sectoral structure of Indonesian trade, as well as the sector-specific price shocks and the export and import elasticities. The assumption of a fixed nominal exchange rate, while appropriate for Cameroon, is not appropriate for Indonesia. The CGE model for Indonesia solves for the nominal exchange rate endogenously, with the aggregate price level set as numeraire. Both models, of course, determine the equilibrium real exchange rate. In the 1-2-3 model, we move to equation (17), which includes both domestic inflation and the nominal exchange rate.

Table 7 compares the CGE model results with those from the PPP and 1-2-3 models. The CGE model yields a real depreciation of 28 percent, which is quite close to the 29 percent figure yielded by the 1-2-3 model. Again, as with the Cameroon example, the 1-2-3 model performs remarkably well in determining the size of the required real exchange rate adjustment, although without the structural detail provided by the CGE model. Note that the "inflation adjustment" figures for the 1-2-3 and CGE models are quite close, even though the foreign price movements are calculated differently. The 1-2-3 world inflation rate comes from equation (17), where the movement in foreign prices is obtained as a weighted sum of export and import inflation, where the weights depend on the average elasticities. The CGE world inflation rate is also a weighted sum of export and import inflation, but with weights based on the base year value of imports and exports. Since trade is nearly balanced and the average elasticities are nearly equal, the weights in each case are approximately the same, so that the inflation numbers are quite close.

[20]The CGE model of Indonesia is described in detail in Devarajan and Lewis (1991).

Table 8: Sectoral Shocks and Initial Trade Data, Indonesia CGE Model

Sector	Percent change in world prices		Base year values (million $)		Trade elasticities (σ and Ω)	
	Imports	Exports	Imports	Exports	Imports	Exports
Food Agriculture	17.7%	16.4%	442.7	147.6	0.6	0.6
Traded Agriculture	17.7%	16.4%	381.5	1376.5	1.7	0.5
Oil, LNG and Coal	27.6%	-31.3%	1532.3	13165.5	0.9	0.6
Other Mining	17.7%	16.4%	201.4	184.0	0.9	0.6
Food, Bev., & Tobacco	17.7%	16.4%	235.0	190.7	0.9	1.2
Textiles & Leather	17.7%	16.4%	167.3	705.5	0.9	0.6
Wood & Furniture	17.7%	16.4%	4.1	1009.5	0.9	0.6
Paper & Other Industry	17.7%	16.4%	348.4	40.2	0.9	2.0
Chemicals & Fertilizer	17.7%	16.4%	2468.3	930.8	0.6	0.5
Non-Metallic Minerals	17.7%	16.4%	236.1	23.6	0.6	2.0
Basic Metals	17.7%	16.4%	885.8	587.0	0.6	0.6
Metal Prod. & Machinery	17.7%	16.4%	6724.0	161.5	0.6	0.6
Elect., Gas & Water	—	—	0.0	0.0	—	—
Construction	—	—	0.0	0.0	—	—
Trade & Storage	17.7%	16.4%	117.6	1357.8	0.4	0.4
Transport	17.7%	16.4%	530.8	625.8	0.4	0.4
Services	17.7%	16.4%	5977.3	596.5	0.4	0.4
Public Administration	—	—	0.0	0.0	—	—
Sum or Average	18.4%	-13.4%	20252.6	21102.5	0.59	0.57

Notes: a dash (—) indicates "not applicable."

Table 9: Equilibrium Exchange Rate Calculations for Indonesia

	PPP Approach:		Model:	
	$ only	$ and yen	1-2-3	CGE
Nominal Devaluation	11.5%	14.6%	45.4%	45.4%
Differential inflation adjustment	11.5%	14.6%	16.4%	17.3%
Real Devaluation	0.0%	0.0%	29.0%	28.1%

Notes: For PPP calculations, real devaluation is zero by assumption, and nominal devaluation equals the inflation adjustment. For the 1-2-3 and CGE models, nominal devaluation is the sum of real devaluation and an inflation adjustment, using the same domestic price inflation figure for both (19.5 percent), which was derived from GDP accounts data.

As a final point, we examine the actual movement of the Indonesian rupiah during this period. The maxi-devaluation in September 1986 was equal to 45 percent, while over the full two years in question, from March 1985 until March 1987, the nominal value of the rupiah depreciated by 50 percent. During this period, the price level rose by about 19.5 percent, so that the real exchange rate depreciated by 31.5 percent. This value is extremely close to the equilibrium devaluations suggested by the 1-2-3 and CGE models. Policymakers evidently recognized that the real terms-of-trade shock required a significant real exchange rate change. Had they only corrected for differential inflation, even using the elasticity-weighted adjustment for differential inflation from the 1-2-3 model, they would have devalued the nominal exchange rate by 16.4%, which is slightly more than a third of the required devaluation of 45.4 percent given by the 1-2-3 model. Using the standard PPP approach yields an even lower estimate (14.6 percent) for the required equilibrium devaluation.

VI. CONCLUSION

Since the mid-1970s, many developing countries have been forced to undertake structural adjustment programs in response to changes in the external environment — particularly a worsening in the international terms of trade and deterioration in the balance of trade. A crucial part of all such programs is a devaluation of the real exchange rate. A common theoretical justification for recommending a real devaluation is based on the Salter-Swan model, where the problem is viewed as achieving a correct set of relative prices between tradable and non-tradable goods. In practice, policymakers use some variant of the purchasing power parity (PPP) approach to compute the new "equilibrium" exchange rate.

In this paper, we discuss the theoretical and empirical shortcomings of these two approaches to computing the equilibrium real exchange rate. We present a small model that distinguishes between imports, exports, and domestic goods and incorporates imperfect substitutability between imports and domestic goods in demand and imperfect transformability between exports and domestic goods in supply. We argue that this 1-2-3 model (one country, two activities, three goods) is an extension of the Salter-Swan model that reconciles the tradable-nontradable goods model with the purchasing-power-parity approach.

Finally, we show how the 1-2-3 model can be used to compute the equilibrium real exchange rate when there are changes in the sustainable balance of trade and in international prices. These estimates depart quite substantially from the PPP approach, which neglects terms-of-trade shocks — arguably the main cause of changes in the equilibrium real exchange rate since the 1970s. We also compare the results from the 1-2-3 model with larger computable general equilibrium (CGE) models, which have been used to analyze issues of structural adjustment in Indonesia and Cameroon. The results indicate that the 1-2-3 model estimates changes in the equilibrium real exchange rate that agree closely with results from larger, more elaborate CGE models. Furthermore, in practice, using the 1-2-3 model to compute changes in the equilibrium exchange rate requires little more information than that required to make PPP calculations, and does much better.

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