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External Shocks, Purchasing Power Parity, and the Equilibrium Real Exchange Rate

Shantayanan Devarajan, Jeffrey D. Lewis, and Sherman Robinson

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 article we resolve these theoretical and empirical difficulties by presenting a model which is a generalization of the Salter-Swan model and which incorporates imperfect substitutes for both imports and exports. Within the framework of this model, the definition of the real exchange rate is consistent both with that of the PPP approach and with that of 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. It also provides a practical way to estimate changes in the equilibrium real exchange rate, requiring little more information than is required to do PPP calculations. The results are consistent with those of multisector computable general equilibrium models, which generalize the trade specification of the small model.

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 International Monetary Fund or World Bank, aimed at facilitating the transition to lower current account deficits. A common ingredient in all these programs is a real depreciation of the exchange rate. A depreciated exchange rate, it is argued, will increase the competitiveness of exports, make imports more expensive, and shift resources from sectors producing nontradables to those producing tradables.

Shantayanan Devarajan is with the Country Economics Department at the World Bank and the John F. Kennedy School of Government at Harvard University; Jeffrey D. Lewis is with the Harvard Institute for International Development at Harvard University; and Sherman Robinson is with the Department of Agricultural and Resource Economics at the University of California at Berkeley. The authors are grateful to Ravi Kanbur, three referees, and two members of the editorial board of this journal for useful comments.

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Implicit in the recommendation of a devaluation is the view that the real exchange rate is out of equilibrium. But by how much is it out of equilibrium? 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 is to calculate the purchasing power parity (PPP) equilibrium exchange rate (Dornbusch 1987; Edwards 1989; Cavallo and Cottani 1986). Following this approach, we define the real PPP exchange rate (R^r) 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):

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

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 postshock period. The equilibrium nominal rate is then calculated by computing the inflation differential between the country and its trading partners since the benchmark year. Because $\hat{R}^r = 0$ 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 will 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 postshock 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 domestic prices using an aggregate price index such as the gross domestic product (GDP) deflator and to measure world prices using a similar aggregate index for the trading partners. One problem with this empirical practice is that the measure of domestic prices includes not only nontradables but also tradables produced or bought by the country, and the measure of world prices includes not only tradables but also nontradables produced by the trading partners. As Edwards (1989) points out, the inclusion of both tradables and nontradables in the index of domestic prices is not a problem for reflecting the direction of change of the relative price of tradables to nontradables. If $P = P_T^{\alpha} P_N^{1-\alpha}$, then $\hat{R} = (1 - \alpha)[\hat{P}_T - \hat{P}_N]$ (where P_T is the price index for tradable goods and P_N is the price index for nontradable goods). Thus the rate of change of the nominal exchange rate, $\hat{R}$, represents

$(1 - \alpha)$ times the change in the ratio of the price index of tradables to the price index of nontradables (P_T to P_N).

An alternative approach is not to use standard aggregate price indexes but, instead, to define separate indexes 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 (Salter 1959; Swan 1960). In addition, a sector might be tradable even if there is no trade observed. Using this definition, even looking at very disaggregated data, there are only a few nontraded 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 whereas 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.

The approach we present in this article resolves these theoretical and empirical difficulties in defining the equilibrium real exchange rate (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 are special cases of this extended model, under restrictive assumptions, and 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.

In section I, we present the extension of the Salter-Swan model. In section II, 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. In section III we discuss alternative approaches and, applying the model to Cameroon and Indonesia, present some illustrative calculations comparing how the different approaches measure changes in the equilibrium exchange rate.

I. 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 that produces two goods—a nontraded domestic good, D, and an export, E. The country also consumes two goods—the domestic good and an import, M. The corresponding prices are P^d, P^e, and P^m. We assume that the country does not consume the export good. (This assumption is not restrictive; if, in fact, the citizens of the country do consume the export commodity, we classify the domestic consumption under D.) 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 domestic and export goods are assumed to be imperfect substitutes. Therefore 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). Alternatively, the domestic and export goods can be viewed as being produced by two different sectors that compete for the same factor that 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. Profit-maximization by producers, given the CET transformation frontier, yields the first-order conditions of equation 3. The relative supplies of the domestic good and exports depend on their relative domestic prices, P^d and P^e, and on the elasticity of transformation, Ω.

The output of the domestic good is also assumed to be an imperfect substitute for imports in consumption, with a constant elasticity of substitution (CES) function (equation 2).[1] The first-order condition for utility-maximizing consumers is given by equation 4, which defines the import demand function. The relative demands for imports and the domestic good depend on their relative domestic prices, P^m and P^d, and on the elasticity of substitution, σ. In this model the domestic good 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-

1. The constant elasticity assumptions are by no means innocuous. Tests of the homotheticity of preferences, for example, have proven quite inconclusive. Hinojosa and Robinson (1991) extend the model to incorporate more general utility functions. For our purposes, however, these functions can be thought of as local approximations.

Table 1. *The 1-2-3 Model*

Item or symbol	*Equation or definition*
Production possibility frontier	(1) $\overline{X} = G(E,D;\Omega)$
Import aggregation function	(2) $Q = F(M,D;\sigma)$
Export supply function	(3) $\frac{E}{D} = g(P^e, P^d; \Omega)$
Import demand function	(4) $\frac{M}{D} = f(P^m, P^d; \sigma)$
Domestic price of imports	(5) $P^m = R \cdot \pi^m$
Domestic price of exports	(6) $P^e = R \cdot \pi^e$
Balance of trade	(7) $\pi^m \cdot M - \pi^e \cdot E = \overline{B}$
Numeraire	(8) $R \equiv 1$
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	Nominal exchange rate
Exogenous variables	
$\overline{X}$	Aggregate output (or GDP)
π^e	World price of exports
π^m	World price of imports
$\overline{B}$	Balance of trade
Ω	Elasticity of transformation in supply
σ	Elasticity of substitution in demand

trade constraint, equation 7. This states that the trade balance (written as imports minus exports) is fixed exogenously at $\bar{B}$.

The system of equations 1 to 8 has eight unknowns: exports, domestic goods sold on the domestic market, imports, the domestic price of exports, the domestic price of the domestic good, the domestic price of imports, the nominal exchange rate, and the composite good (absorption). Note that any solution to the system depends only on relative prices. The system is a general equilibrium model with two production activities (exports and domestic goods) and three distinct goods (export, domestic, and import). We have implicitly introduced the equilibrium condition on the domestic market by using the same domestic good variable for both supply (in equations 1 and 3) and demand (equations 2 and 4). Furthermore, Walras's law is satisfied because, by premultiplying equation 7 by the nominal exchange rate 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.

The 1-2-3 model contains no monetary elements: it only determines relative prices; the balance of trade is exogenous; and there are neither assets nor any financial variables. It is a "real" model that identifies an equilibrium relationship (between the real exchange rate and the trade balance) which should be an essential feature of any macroeconomic model concerned with structural adjustment. As described here, the 1-2-3 model contains no explicit policy instruments, but it can be—and has been—extended to include, for example, taxes and government expenditure (Devarajan and de Melo 1987; Devarajan, Lewis, and Robinson 1990).

II. The Analytics of the Equilibrium Real Exchange Rate

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

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

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

The various share parameters in the CES and CET functions have been gathered into the constant terms in equations 9 and 10. Alternatively, equations 9 and 10 can be seen as local approximations of arbitrary import-demand and export-supply functions. If a nonhomothetic function is used, equations 9 and 10 will include an income effect.

In addition, we rewrite the balance of trade equation, specifying the balance of trade, B, as a share of export earnings $(\lambda - 1)$:

$$\pi^m \cdot M = \lambda \cdot \pi^e \cdot E \tag{11}$$

where

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

The parameter λ can be interpreted as the country's sustainable balance of trade, or the proportion by which imports can exceed exports. Thus, a trade balance of zero corresponds to a λ of 1. This treatment is convenient when considering proportional changes, because the rate of growth of λ is well defined, even when the balance of trade is initially zero. Note that when the balance of trade is initially different from zero, a fixed λ does not correspond to a fixed balance of trade, because the balance of trade will vary with the value of exports.

Log differentiation ($\text{dlog}(X) = \hat{X} = dX/X$) of equations 9 to 11 yields:

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

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

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

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

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 the nominal exchange rate as the numeraire price, the numerator in both measures is fixed by world prices. The only endogenous price in the model is the domestic price of the domestic good, which is common to both. Shocks that do not involve changes in world prices (such as a change in foreign capital inflow) will only affect the domestic price of the domestic good and hence will affect both real exchange rate measures identically.

Because the price of the domestic good is the important relative price determining the real exchange rate, we want to solve for it in terms of the rates of change in the world price of imports and the world price of exports ($\hat{\pi}^m$ and $\hat{\pi}^e$), and changes in the sustainable trade balance ($\hat{\lambda}$). Subtracting equation 14 from equation 13, substituting for $\hat{M} - \hat{E}$ in equation 15, and manipulating yields

$$\hat{P}^d = \frac{1}{\sigma + \Omega}[(\sigma - 1) \cdot \hat{\pi}^m + (1 + \Omega) \cdot \hat{\pi}^e + \hat{\lambda}]. \tag{16}$$

Equation 16 is the core result. It gives the equilibrium change in the price of the domestic good for a given change in world prices or in foreign capital inflows, under the assumption that $\hat{R} = 0$. Note that we are assuming that the changes in terms of trade are permanent and that the shift in λ will persist.[2] To facilitate comparison with the PPP approach, equation 16 can be rewritten with the rate of change in the nominal exchange rate included explicitly through a calculation of the price level deflated (PLD) exchange rate. The price level deflated exchange rate is defined in Krueger (1978) and Bhagwati (1978); here we specify a particular choice of price index for deflating the nominal exchange rate. Rearranging the terms from equation 16, the equilibrium PLD exchange rate is defined as:

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

The first term on the right of equation 17 adjusts the equilibrium PLD exchange rate for world inflation, the second term accounts for any change in the interna-

2. If nonhomothetic import-demand or export-supply functions are used, equation 16 will include an additional income-related term reflecting the difference in expenditure elasticities of import demand and export supply.

tional terms of trade, and the third term accounts for any change in the sustainable balance of trade, where the sustainable level of foreign capital inflow is defined as a share of exports rather than as a fixed value.

Equation 17 can be rearranged to define a real PPP exchange rate variable, R^r, whose rate of change, $\hat{R}^r$, equals the change in the nominal exchange rate 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 effect of differential inflation. In practice, the PPP approach ignores the terms of trade effect and handles the balance of trade effect by starting from a base in which the balance of trade is assumed to be in equilibrium (hence $\hat{\lambda} = 0$). Equation 18 indicates that in the 1-2-3 model the equilibrium real PPP exchange rate will change only when there are changes in the international terms of trade or in the balance of trade. There is a conceptual similarity between equation 18 and the standard PPP approach, because the term in brackets in equation 18 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 in equation 18, however, are substitution and transformation elasticities, not trade shares, which are commonly used in defining world price indexes in the PPP approach.

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 PPP 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 standard PPP approach to computing changes in the equilibrium exchange rate is valid if, and only if there is no change in the international terms of trade and in the equilibrium, or sustainable, level of foreign capital inflow.

As either the elasticity of substitution in demand or the elasticity of transformation in supply (σ or Ω) approaches infinity, the model collapses to the standard small-country model, in which all goods are 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 because the domestic price of the perfect substitute (either for exports or imports) is determined by the exogenous world price. In such models, the exchange rate has no role in determining relative prices.

Consider now the impact of a change only 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, whereby the real exchange rate appreciates 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 the price of the domestic good rises or falls depends on the value of the elasticity of substitution between imports and domestic goods. If the elasticity 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 the elasticity 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. The volume of trade also falls. The effects 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). The authors derive an explicit expression for the country's offer curve, solving for quantity as well as price effects.

In practice, it is common to define a single real exchange rate by 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, as called for in equation 16. These alternative indexes, however, include tradables. In the 1-2-3 model, the consumer price index corresponds to the price of the composite good purchased by consumers, and the GDP deflator corresponds to the price of domestic output. An index of composite good prices includes imports but excludes exports, and a domestic output index includes exports but excludes imports. However, it is straightforward to construct an appropriate index for domestically produced goods that are consumed domestically, based on national accounts data. The index can be constructed by removing export prices from the GDP deflator, using the expenditure identity

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

(19)
$$P^d = \frac{P^x - S^e \cdot P^e}{1 - S^e}$$

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

The 1-2-3 model can also be linked with other approaches to calculating the real exchange rate. For example, the elasticities approach (see Krueger, Schiff, and Valdés 1988; Mundlak, Cavallo, and Domenech 1990; Dixit and Norman

1980) extends earlier work applying the elasticities approach to the balance of payments to argue that the real exchange rate should be related to the elasticities of demand for and supply of foreign exchange.

Krueger, Schiff, and Valdés (1988) present a formula that is similar to equation 16, but 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 relies on a reduced-form equation without specification of the underlying structural model, which can lead to varying views of the appropriate structural model. For example, Krueger, Schiff, and Valdés (1988) assume that the entire nonagricultural sector consists of nontradable goods and services. Such an assumption, although convenient in their analysis, is at odds with the stylized facts characterizing most developing countries and plays no part in 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. As in the 1-2-3 model, they specify different real exchange rates for supply and demand. They also obtain results that are similar to those obtained from the 1-2-3 model: the responses to a terms of trade shock are different on the real exchange rates for supply and demand. Indeed, the 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 the 1-2-3 model. Although Mundlak, Cavallo, and Domenech (1990, 57) note the possibility that the exchange rate will appreciate when there is a "low value of ω," the 1-2-3 model 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 $\sigma < 1$. Moreover, they specify all three goods as domestically produced, and although they acknowledge that in Argentina "almost no domestically produced agricultural products are also imported", their framework makes it difficult for them to estimate the price of the home good; they argue that ". . . by the very fact that the home sector is not well defined, there are no direct observations on [its price]" (Mundlak, Cavallo, and Domenech 1990, 64). As the 1-2-3 model demonstrates, not only is the home sector well defined, but, in addition, its aggregate price is obtainable from national accounts data.

The 1-2-3 model also resembles the "fundamentals" approach to calculating the ERER (Williamson 1983). The fundamentals approach incorporates changes in external circumstances and domestic policy in determining the ERER, and is based on a reduced-form model. It also seeks to capture intertemporal elements that our static model ignores.

III. Empirical Examples

We illustrate our method of calculating the equilibrium real exchange rate (ERER) by applying the 1-2-3 model to Cameroon and Indonesia. Both countries 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, because 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 computable general equilibrium (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.

Trade-focused, multisector CGE models, which generalize the trade specification of the 1-2-3 model, have been used to analyze structural adjustment in developing countries. 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 (Dervis and Robinson 1982; Lewis and Urata 1984), Yugoslavia (Robinson and Tyson 1985), and Hungary (Kis, Robinson, and Tyson 1990) indicate that standard PPP calculations of the change in the equilibrium exchange rate can be badly off the mark, greatly underestimating the required devaluation. While supporting the arguments made in this article, these studies represent major research efforts and do not offer a simple alternative to the PPP approach. The question addressed below is, instead, 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 while at the same time remaining compatible with more disaggregated CGE models.

Cameroon

From 1982 to 1986, 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. (Unless otherwise indicated, all data in this subsection are from World Bank 1989.) 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 nonfactor 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 consumer price index [CPI]) also rose by 31 percent during this period, and the exchange rate between the two countries was fixed (International Monetary Fund 1989). Honohan (1990) shows that inflation in the CFA countries as a whole was not significantly different from French inflation during 1965–88. In terms of domestic versus foreign inflation, Cameroon's real PPP exchange rate was evidently in equilibrium in 1986, despite the sizable deterioration in the terms of trade.

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. With the 1-2-3 model, we can take the relative price shock into account when estimating the change in the ERER. In doing so for Cameroon, we assume that the only shock facing the country was the change in international prices. Table 2 shows the change in the domestic price level during 1982–86 for different values of the export transformation and import substitution elasticities, given the actual changes in average export and import prices (–28 and +12 percent, respectively). The calculations use equation 16.

The estimation of the export transformation and import substitution elasticities is clearly difficult in countries with limited data. Furthermore, as table 2 shows, numerical results from the 1-2-3 model are quite sensitive to these values, with the equilibrium changes in the domestic price level ranging from −28 to −88 percent, depending on the elasticities. One approach to estimating elasticities is to use values that represent the weighted average of sector-specific elasticities. Using sectoral values for the export transformation and import substitution elasticity for Cameroon presented in table 3 (taken from an 11-sector model of Cameroon) yields an average export elasticity of 0.5 and an import elasticity of 0.6.

Using these average elasticities, the decline in the domestic price level required to achieve equilibrium is 46.2 percent. Using the decomposition in equation 18, the equilibrium real devaluation is 36.4 percent, which is a far cry from the 0 percent prescribed by the usual PPP approach. Assuming that $\hat{R}$ is equal to zero, 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

Table 2. *Changes in the Equilibrium Domestic Price Level in Cameroon, 1982–86*
(percent)

Export transformation elasticity (Ω)	*Import substitution elasticity* (σ)			
	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

Note: Values are the percentage change in the domestic prices caused by a 12 percent change in import prices and a −28 percent change in export prices. The nominal exchange rate and the balance of trade are assumed to be unchanged.

Table 3. *Sectoral Shocks and Initial Trade Data,* CGE *Model for Cameroon*

Sector	*Percentage change in world price, 1982–86*		*Base-year level (billions of 1985 CFA francs)*		*Elasticity*
	Imports	*Exports*	*Imports*	*Exports*	
Capital goods	20	—	448.9	20.6	0.40
Cash crops	—	−40	11.8	232.5	0.90
Cement	—	—	65.8	35.9	0.75
Construction	—	—	0.0	0.0	0.00
Consumer goods	25	—	37.2	12.4	1.25
Food crops	—	—	11.1	5.5	1.50
Food processing	—	—	22.9	15.8	1.25
Forestry	—	—	0.0	24.9	0.40
Intermediate goods	20	−50	208.6	379.6	0.50
Private services	—	—	245.6	222.2	0.40
Public services	—	—	0.0	0.0	0.00

— No change.
Note: Import substitution and export transformation elasticities are the same in each sector.

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 percent = 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 11-sector CGE model of Cameroon. (The CGE model of Cameroon is described in detail in Benjamin, Devarajan, and Weiner 1989.) Table 3 describes the sector-specific world-price shocks that 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 3 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.

Indonesia

The combination of plummeting oil prices and international currency realignment that began in late 1985 signaled an abrupt and painful end to the boom years in Indonesia. Not only did the price of oil drop from more than $30 a barrel to $10 a barrel 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 nondollar currencies, including 40 percent denominated in yen).

Faced with a terms of trade shock of this magnitude, the exchange rate came under pressure. 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.

With the PPP approach, the appropriate exchange rate 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 for the PPP calculation. In no year since 1974 did Indonesia's current account come 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).[3] An alternative way to choose a benchmark is to define a sustainable deficit as that of 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 1987/88, the Indonesian 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 11.6 percent to restore the real exchange rate to its equilibrium value. But focusing only on dollar inflation seems incorrect because 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.

Table 4. *Changes in the Equilibrium Domestic Price Level in Indonesia, 1985–87*
(percent)

Export transformation elasticity (Ω)	*Import substitution elasticity (σ)* 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

Note: Values are the percentage change in the domestic price caused by an 18 percent increase in import prices, a 13 percent decrease in export prices, and a 2.6 percent decline in the sustainable balance of trade. The nominal exchange rate is assumed to be unchanged.

3. 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."

Table 5. *Sectoral Shocks and Initial Trade Data,* CGE *Model for Indonesia*

Sector	Percentage change in world price, 1985–87		Base-year value, 1985 (millions of dollars)		Trade elasticities	
	Imports	Exports	Imports	Exports	Imports (σ)	Exports (Ω)
Basic metals	17.7	16.4	885.8	587.0	0.6	0.6
Chemicals and fertilizer	17.7	16.4	2,468.3	930.8	0.6	0.5
Construction	—	—	0.0	0.0	—	—
Electricity, gas, and water	—	—	0.0	0.0	—	—
Food agriculture	17.7	16.4	442.7	147.6	0.6	0.6
Food, beverages, and tobacco	17.7	16.4	235.0	190.7	0.9	1.2
Metal products and machinery	17.7	16.4	6,724.0	161.5	0.6	0.6
Nonmetallic minerals	17.7	16.4	236.1	23.6	0.6	2.0
Oil, LNG[a] and coal	27.6	−31.3	1,532.3	13,165.5	0.9	0.6
Other mining	17.7	16.4	201.4	184.0	0.9	0.6
Paper and other industry	17.7	16.4	348.4	40.2	0.9	2.0
Public administration	—	—	0.0	0.0	—	—
Services	17.7	16.4	5,977.3	596.5	0.4	0.4
Textiles and leather	17.7	16.4	167.3	705.5	0.9	0.6
Trade and storage	17.7	16.4	117.6	1,357.8	0.4	0.4
Traded agriculture	17.7	16.4	381.5	1,376.5	1.7	0.5
Transport	17.7	16.4	530.8	625.8	0.4	0.4
Wood and furniture	17.7	16.4	4.1	1,009.5	0.9	0.6
Sum or average	18.4	−13.4	20,252.6	21,102.5	0.59	0.57

— Not applicable.
a. Liquified natural gas.

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 in 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 prices rose by 18 percent (World Bank data).

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, and the balance of trade declines by 2.6 percent (measured by $\hat{\lambda}$). The equilibrium domestic price movements range from -65 to -14 percent, depending on the elasticities. The middle row and column ($\Omega = 0.57$ and $\sigma =$

0.59) are reasonable elasticity values for Indonesia and were obtained through a traded-weighted average of the sectoral elasticities presented in table 5. With these average parameter values, the domestic price is estimated to decline by 26 percent (assuming $\hat{R} = 0$). Of this 26 percent, 27 percent is due to the terms of trade shock, 2 percent to the change in the trade balance, and −3 percent to the change in world prices.

To facilitate comparison of these results with the PPP model, table 6 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 with 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, and only 2 percentage points are due to the change in the balance of trade.

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 the same terms of trade shock using an 18-sector CGE model of Indonesia, a model described in detail in Devarajan and Lewis (1991) and Lewis (1991). Table 5 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 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. 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 move-

Table 6. *Equilibrium Real Exchange Rate Depreciation in Indonesia, 1985–87*
(percent)

Export transformation elasticity (Ω)	*Import substitution elasticity (σ)* 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

Note: Values are the percentage change in the equilibrium real exchange rate caused by an 18 percent increase in import prices, a 13 percent decrease in export prices, and a 2.6 percent decline in the sustainable balance of trade.

Table 7. *Equilibrium Exchange Rate Devaluation, Calculations for Indonesia, 1985–87*
(percent)

	PPP approach			
	Dollar only	*Dollar and yen*	*1-2-3 model*	*CGE model*
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

Note: 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). The price inflation figure is derived from GDP accounts data.

ments 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, the weights depending 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. Because trade is nearly balanced and the average elasticities are nearly equal, the weights in each case are approximately the same. Therefore the inflation numbers are quite close.

IV. Conclusion

In this article, we discuss the theoretical and empirical shortcomings of different 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 is an extension of the Salter-Swan model, and that it reconciles the tradable-nontradable goods model with the purchasing-power-parity approach.

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. Estimates using this model depart quite substantially from those using the PPP approach, which neglects terms of trade shocks—arguably the main cause of changes in the equilibrium real exchange rate since the 1970s. The results from the 1-2-3 model agree closely with the results from larger computable general equilibrium (CGE) models. The 1-2-3 model estimates of changes in the equilibrium real exchange rate agree closely with those obtained from larger, more elaborate CGE models, such as have been used to analyze issues of structural adjustment in Cameroon and Indonesia. In practice, using the 1-2-3 model to compute changes in the equilibrium real exchange rate requires little more information than is required to make PPP calculations.

The 1-2-3 model does require information to calculate two elasticities whose values are difficult to estimate with limited data. And the required real exchange rate depreciation can be quite sensitive to these elasticities. Nevertheless, experience with larger models as well as empirical estimation in some countries helps us narrow the range of values for these elasticities, thereby narrowing the range of estimates of the required depreciation.

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