Abstract

This paper examines the relative demands for domestic and foreign currency deposits by residents of developing countries. A dynamic currency substitution model that incorporates forward-looking rational expectations is formulated and then estimated for a group of ten developing countries. The results indicate that the foreign rate of interest and the expected rate of depreciation of the parallel market exchange rate are important factors in the choice between holding domestic money or switching to foreign currency deposits held abroad. From an empirical standpoint, the forward-looking framework adopted here also turns out to be superior to the conventional currency-substitution model.

JEL Classification Numbers:
E41, F32, C52

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I. Introduction

Currency substitution—the process whereby foreign money holdings substitute for domestic money balances as a store of value, unit of account, and medium of exchange—has become a pervasive phenomenon in many developing countries. Such substitution, or "dollarization”, has been observed in countries that differ widely in levels of financial development, in the degree of integration with the rest of the world, and in types of exchange rate regimes and practices. In some cases, particularly where high and variable inflation rates and uncertainty about domestic policies have prevailed for a substantial period of time, the use of foreign currency has become so prevalent that even most domestic sales and contracts are transacted in foreign currency. 1/

The consequences of an increase in the holdings of foreign money are well recognized. In the short run, for example, a rise in foreign currency deposits, which is equivalent to a capital outflow, can have potentially destabilizing effects on domestic interest rates, the exchange rate, and international reserves. Thus, macroeconomic policy would need to be sensitive to the degree and extent of substitution possibilities between domestic and foreign deposits. For example, a capital outflow creates a shortage of liquidity in the system, which in turn would push up domestic interest rates. The outflow would also tend to depreciate the domestic currency under a floating exchange rate regime. On the other hand, if the government is committed to defending a particular exchange rate, it will deplete its reserves. In either case, an increase in the demand for foreign currency deposits would cause short-run adjustment problems for the government. Furthermore, when a country is facing a balance of payments crisis, or is heading toward one, and immediate corrective policy action is not taken, residents of the country, foreseeing the possible problems (of increasing inflation, devaluation, imposition of exchange controls, and so on) are likely to increase transfers abroad. Consequently, at the very time that foreign exchange resources are required by the country, agents engage in shifting funds abroad, thereby exacerbating the crisis. Also, the shift to foreign currency deposits held abroad reduces the government’s ability to tax all the income of its residents, mainly because governments have difficulty in taxing wealth held abroad as well as the income that is generated from that wealth. As government revenues fall with the erosion of the tax base, there is likely to be a worsening of the fiscal position and an increased need to borrow, thereby increasing the domestic and foreign debt burdens.

1/ A third factor explaining the increase in currency substitution is to be found in recent technological advances in communication and financial management, which have provided a substantial fall in the cost of transferring funds across country borders.
Several empirical studies on currency substitution in developing countries have been conducted over the past few years in an effort to isolate the factors that give rise to this phenomenon. 1/ Most of the studies, however, are based on two somewhat restrictive assumptions. The first is that existing empirical models implicitly impute "myopic" behavior to the agents whose decisions they describe, by assuming that these agents determine the optimal composition of their money holdings without regard for the future. When--usually at the estimation stage--dynamic features are introduced, they almost invariably take the form of the addition of the (one-period) lagged dependent variable, with partial adjustment frequently being invoked as a rationalization. 2/ The restrictive nature of this approach to dynamic modeling in econometrics has been clearly demonstrated (see for instance Hendry et al., 1984). In the first instance, this procedure unduly constrains the lag structure at the outset of the empirical investigation. Furthermore, the estimated coefficients of the lagged dependent variable are usually large, implying implausibly long adjustment lags. Similarly, when expectations are introduced, it is generally through a backward-looking process, such as adaptive expectations. However, the adaptive expectations hypothesis has been shown to be optimal only under somewhat restrictive circumstances (see, for instance, Pesaran, 1988).

A second limitation of existing studies results from the fact that the degree of currency substitution is usually estimated without explicitly accounting for the existence of foreign currency holdings. This occurs in part because of the notorious difficulties involved in estimating comprehensively the existing stocks of such assets. A number of countries have, however, allowed foreign currency deposits in their banking system. 3/ Such data have not, however, been...

1/ Recent econometric studies on currency substitution include studies on Argentina (Fasano-Filho, 1988, and Ramirez-Rojas, 1985), Bolivia (Melvin, 1988), the Dominican Republic (Canto, 1985), Brazil (Calomiris, and Domowitz, 1989), Ecuador (Canto and Nickelsburg, 1987), Egypt (El-Erian, 1988, and Haque, 1990), Mexico (Melvin, 1988, and Ortiz, 1983), Uruguay (de Melo, 1987, and Ramirez-Rojas, 1987), and Venezuela (Marquez, 1987, and Canto and Nickelsburg, 1987). For a general discussion, see Tanzi and Blejer (1982).

2/ This tendency seems to result from the influence of the literature on money demand. Discussions and generalizations of the partial adjustment framework are given by Hwang (1985) and Goldfeld and Sichel (1987, 1990).

3/ See Dodsworth, El-Erian and Hammann (1987) for a discussion of the evolution and implications of domestic holdings of foreign currency bank deposits in developing countries. In Egypt for instance, a large percentage of the foreign currency deposits in the domestic banking system are held in the form of interest-bearing time...
systematically exploited in the existing literature. Moreover, researchers in this area have ignored data collected and published by the International Monetary Fund on foreign currency deposits held abroad by country of origin of residents. Although such data are not comprehensive, they provide information that could prove quite useful in studies of currency substitution.

The purpose of this paper is to formulate and estimate a dynamic, forward-looking model of currency substitution, using data on deposits held abroad for a group of ten developing countries—Bangladesh, Brazil, Ecuador, Indonesia, Malaysia, Mexico, Morocco, Nigeria, Pakistan and the Philippines. The model, which incorporates the assumption of rational expectations, is developed in two steps. The desired composition of currency holdings is first derived from an optimizing model of household behavior. Actual currency holdings are then determined in a multi-period costs of adjustment framework, following an approach that has been developed in the recent literature on "buffer stock money", notably by Cuthberson and Taylor (1987, 1990). The multi-period costs-of-adjustment framework results in an empirical specification that incorporates both backward- and forward-looking components. One of the particularly appealing features of the empirical implementation of the model is that it does not require information on the domestic interest rate. In previous studies, the lack of a suitable domestic interest rate series has inhibited the estimation of currency substitution models relying on relative rates of return between domestic and foreign currencies that are based on interest rates. The approach taken here circumvents this particular problem, utilizing instead data on the foreign interest rate and the premium on the domestic currency in the parallel exchange market. The model is estimated using quarterly data for a group of ten developing countries by an errors-in-variables procedure. For comparison purposes, an alternative model based on a conventional, partial adjustment formulation is also estimated. The alternative models are then compared on the basis of tests on properties of residuals, forecasting capabilities, and by a statistical technique for comparing non-nested models.

The remainder of the paper is divided into four sections. The next section describes the behavior of foreign currency deposits held abroad by developing-country residents over the past decade. Section III presents the theoretical framework. Section IV outlines the estimation procedure, presents the empirical results, and compares the

3/ (cont'd from p. 2) deposits. Prior to November 1982, dollar-denominated bank deposits were legal in Bolivia, but were suspended at that time until September 1985.

1/ Studies in which data on domestic foreign currency deposits have been exploited in a study of currency substitution include El-Erian (1988), Haque (1990) and Melvin (1988).
statistical properties of the model with those of the conventional currency-substitution model. Finally, the concluding section (Section V) provides an overall assessment of the analysis.

II. Overseas Foreign Currency Deposits: An Overview

Since the early 1980s, the International Monetary Fund has been collecting and publishing data on foreign currency deposits held abroad by residents of a large number of developing countries. Table 1 shows the average magnitude of these deposits for various regional groupings of developing countries over the period 1981-90, and Figure 1 depicts their evolution over time.

The data in Table 1 indicate that foreign currency deposits have averaged about $270 billion for all developing countries during the decade of the eighties, with nearly half this amount being held by residents of Latin America. The Middle East region accounted for about $70 billion, followed by Asia ($40 billion) and Africa ($20 billion). The developing countries in Europe showed the lowest amount, about $6 billion.

These figures, while large in absolute terms, are even more striking when expressed as a proportion of foreign exchange reserves and trade flows. For developing countries as a whole, foreign currency deposits held abroad were over 120 percent of the official foreign exchange reserves; for Latin America they were nearly four times the level of official reserves. The proportions for Africa (205 percent) and the Middle East (121 percent) are also sizable. The corresponding figures for Asia (41 percent) and Europe (54 percent) appear quite modest by comparison to the other regional groupings. As a proportion of exports and imports, for all developing countries foreign currency deposits held abroad amounted to about 42 percent. Again, the picture for Latin America is quite dramatic, where such deposits were 130 percent of exports and 153 percent of imports. The corresponding ratios for the other three regional groupings are much smaller, but by no means insignificant. For example, in the case of Africa the reserves-to-import ratio averaged only about 15 percent, while the ratio of foreign currency deposits to imports was over 30 percent.

The growth of foreign currency deposits held abroad has also been very rapid in the 1980s (Figure 1). Panel 1 of the Figure indicates

1/ These data are defined as "cross-border bank deposits of nonbanks by residence of depositor," and are derived from reports on the geographic distribution of the foreign assets and liabilities of deposit banks made by the authorities of 33 international banking centers.
Table 1. Overseas Foreign Currency Deposits 1/

<table>
<thead>
<tr>
<th>Region</th>
<th>Billions of US dollars</th>
<th>In Proportion of: 2/</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Reserves 2/</td>
</tr>
<tr>
<td>Developing Countries</td>
<td>269.7</td>
<td>121.3</td>
</tr>
<tr>
<td>Africa</td>
<td>20.5</td>
<td>204.8</td>
</tr>
<tr>
<td>Asia</td>
<td>39.4</td>
<td>40.6</td>
</tr>
<tr>
<td>Europe</td>
<td>5.7</td>
<td>53.8</td>
</tr>
<tr>
<td>Middle East</td>
<td>70.8</td>
<td>121.5</td>
</tr>
<tr>
<td>Latin America</td>
<td>133.4</td>
<td>385.9</td>
</tr>
</tbody>
</table>


1/ Figures are averages over 1981-90, except for the Middle East region, for which the period averages cover 1981-87.

2/ Percent.

3/ Excluding gold.
that these deposits rose from about $80 billion in 1981 to $450 billion by the end of 1990--an annual average rate of increase of nearly 50 percent. For Latin America, the annual average growth rate was over 70 percent, while that for African countries was around 60 percent. The ratios of foreign currency deposits to foreign exchange reserves has remained relatively stable (Panel 2 of Figure 1), except for Latin America, where the phenomenon seems to stem to a large extent from the acceleration of capital flight during the 1980s.

Notwithstanding the fact that foreign currency deposits held abroad by residents are large by most standards, and growing over time, it is worth noting that the data do not capture the full extent of foreign currency holdings. To obtain a more accurate measure one would need to add foreign currency deposits in domestic banks, as well as foreign currency notes in the hands of the public. Few developing countries allow foreign currency deposits in the domestic banking system--although the number is rising--and data on foreign currency notes in circulation is virtually impossible to obtain. Furthermore, the IMF data do not capture "arms length" transactions, where the deposit of the developing-country resident is held in the name of a foreign resident in a foreign bank. All in all, the published data on foreign currency deposits abroad probably represent a lower bound of the amount of foreign money balances held by residents of developing countries.

Foreign currency deposits may be held abroad for a variety of reasons: for financing (legal and illegal) imports and other expenditures abroad, for protection of financial wealth, for speculation, and for capital flight. Even in countries where foreign currency deposits are legally allowed, a lack of confidence in the stability of the domestic banking system and/or the government's commitment to guarantee deposits in foreign exchange will typically provide an incentive to hold financial assets abroad rather than at home. In general, the actual level of foreign currency deposits abroad, relative to domestic deposits, should depend on their respective risk-adjusted rates of return. This relationship forms the basis of the formal portfolio diversification model developed in the next section.

III. An Optimizing Model with Foreign Currency Balances

This section develops a dynamic model of currency holdings with forward-looking rational expectations in a developing-country context. The model is developed in two steps. The desired composition of currency holdings is first derived from an optimizing model of household behavior. In the second step, actual currency holdings are determined in a multi-period costs of adjustment framework.
FIGURE 1. FOREIGN CURRENCY DEPOSITS HELD ABROAD (1981-1990)

(Billions of US dollars)

(In proportion of reserves, excluding gold)
1. Optimal composition of currency holdings

The hypothetical world of this model consists of a small open developing economy with no commercial banks and a dual exchange rate regime. The dual exchange market consists of an official market for foreign exchange, in which the official parity is pegged, which coexists with a legal or quasi-legal parallel market for foreign exchange. Commercial transactions are settled partly in the official market at the official exchange rate $\tilde{e}_t$. The rest of commercial transactions and all capital transactions are settled in the parallel market at the free exchange rate $s_t$, which is determined by market forces. 1/

Total output, which consists of a single exportable good only, is assumed to be fixed at level $\Theta$. The price of the good is set on world markets. In each period, producers surrender a given proportion of their foreign exchange earnings at the official exchange rate, and repatriate the remaining proceeds via the parallel market. There is no domestic expenditure on the domestically produced good; thus, total output is exported and total consumption is imported. Domestic agents consume two goods, both of them produced abroad. 2/ The first good is imported through legal channels, without restriction, at the official exchange rate. The second good is assumed to be prohibited by law, and thus can only be smuggled in and traded illegally in the economy. 3/ The domestic price of the legally imported good is therefore influenced by the official exchange rate, and is given by $e_t p_w$ under purchasing power parity, where $p_w$ denotes the (given) world price. Similarly, the domestic price of the smuggled good reflects the marginal cost of foreign exchange (that is, the parallel market rate) and is given by $s_t \tilde{p}_w$. In what follows, the price of the legally imported good is used as the numeraire. Setting $p_w = \tilde{p}_w = 1$, the unit

1/ Both $e_t$ and $s_t$ are defined as the number of units of foreign currency per unit of domestic currency.

2/ The model could, alternatively, be developed in a one-good framework, without affecting its major implications. A problem with the one-good model, however, is that it is difficult to explain why the same good should be traded at two different prices in an economy with competitive suppliers. In a socialist economy, the one-good framework may be more appropriate since allocation through the official market is subject to government regulations. See Lane (1991) for a model along these lines.

3/ Alternatively, the second good can be a "luxury good" that cannot be imported at the official exchange rate, but can be imported legally through the parallel market.
of account is therefore the official exchange rate, while the relative price of the legally imported good in terms of the illegally traded good, is given by the inverse of (one plus) the parallel market premium, defined as \( \rho_t = s_t/e_t \).

Residents are assumed to hold four types of assets: domestic money, foreign money, bonds denominated in domestic currency, and bonds denominated in foreign currency. The domestic-currency bond yields \( i \) units of domestic currency after one period of time and has a fixed face value equal to one unit of domestic money. The foreign-currency bond pays \( i^* \) units of foreign currency after one period and has a face value of one foreign-currency unit. Domestic and foreign money are imperfectly substitutable, non-interest-bearing assets. 1/ Following Calvo and Végh (1990), domestic agents hold foreign currency as well as besides their own currency because of a "liquidity-in-advance" constraint on purchases of both goods. 2/ Goods are perishable so that domestic residents must allocate their wealth, in each period, between the available financial assets.

There is a single representative agent who maximizes a discounted sum of future instantaneous utilities. The individual's objective function takes the form 3/

\[
\sum_{t=0}^{\infty} \gamma^t V(c_t, \bar{c}_t),
\]

where \( \gamma = 1/(1 + r) \), and \( r \) is the positive rate of time preference. 4/

At the beginning of every period \( t \), the agent holds \( M_{t-1} \) units of domestic money, \( F_{t-1} \) units of foreign money, \( B_{t-1} \) units of domestic-currency bonds, and \( B^*_{t-1} \) units of foreign-currency bonds. He then

1/ Some restrictions are assumed to be in force to limit substitutability between currencies; otherwise, the Kareken-Wallace indeterminacy result would hold (see Sargent, 1987b, pp. 188-92).

2/ See also Bohn (1991) for a model of the transactions demand for money with a cash-in-advance constraint. Alternatively, it could be assumed that agents choose to hold domestic and foreign currencies so as to economize on the transactions costs of exchange as, for instance, in Végh (1989) and Rogers (1990).

3/ For simplicity, the presentation of the model assumes away uncertainty. Uncertainty is explicitly accounted for in the determination of the actual currency ratio.

4/ \( V(.) \) is defined for all \( (c_t, \bar{c}_t) > (0, 0) \), and is assumed to be strictly concave and twice continuously differentiable.
receives his endowment, and nominal interest payments \( i_{t-1}B_{t-1} \) and \( i^*_t b^*_t \), and decides on consumption of imported goods. He allocates his implied end-of-period nominal assets \( A_t \) among \( M_t, F_t, B_t \) and \( b^*_t \).

Formally, the individual's accumulation program must satisfy the constraints

\[
A_t = M_t + B_t + s_t (b^*_t + F_t),
\]

\[
\Delta A_t = A_t - A_{t-1} = (1 - \sigma)\bar{e}_t \Theta + \sigma s_t \Theta + i_{t-1}B_{t-1} + \bar{e}_t i^*_t b^*_t - (\bar{e}_t c_t + s_t c_t) + \Delta s_t (b^*_t + F_{t-1}).
\]

Equation (2) defines nominal wealth as the sum of holdings of domestic and foreign currency, and holdings of domestic and foreign bonds. \( L \) Equation (3) represents the flow budget constraint of domestic consumers. The parameter \( \sigma \) denotes the fraction of total export earnings repatriated via the parallel market, and for simplicity is assumed to be constant. \( 2 \) The domestic-currency value of exports channelled through the official market for foreign exchange is therefore \((1 - \sigma)\bar{e}_t \Theta \). Interest payments on foreign bonds, \( i^*_t b^*_t \), are assumed to be repatriated at the official exchange rate.

The quantities of the legally and illegally imported goods consumed by domestic agents are given by \( c_t \) and \( \bar{c}_t \), respectively. The last term in equation (3) represents valuation effects on the stock of foreign currency and foreign bonds.

Dividing equation (2) by \( \bar{e}_t \) yields real wealth (measured in terms of the price of the legally imported good) as:

\[
a_t = m_t + b_t + \rho_t (b^*_t + F_t),
\]

where \( a_t = A_t /\bar{e}_t \), \( m_t = M_t /\bar{e}_t \), and \( b_t = B_t /\bar{e}_t \). Similarly, dividing equation (3) by \( \bar{e}_t \) and re-arranging yields:

\( L \) Foreign currency holdings and holdings of foreign bonds are valued at the unofficial exchange rate, because capital transactions are settled in the parallel market.

\( 2 \) In a more general formulation \( \sigma \) would be endogenous and related to the size of the parallel market premium as, for instance, in Bhandari and Végh (1990).
In addition to constraints (2) and (3), consumers are subject to a liquidity-in-advance constraint, which "forces" them to hold both domestic and foreign money in order to carry out transactions: \textsuperscript{1/}

\[ c_t + \rho_t e_t \leq L(m_t, \rho_t F_t). \tag{4} \]

Equation (4) indicates that total real expenditure on both goods cannot exceed the flow of liquidity services produced by the use of domestic and foreign currencies. \textsuperscript{2/} The "liquidity services" production function \( L(.) \) is assumed concave, homogeneous of degree one, twice-continuously differentiable, with partial derivatives given by \textsuperscript{3/}

\[ \frac{\partial L}{\partial m} > 0, \quad \frac{\partial L}{\partial (\rho F)} > 0, \]
\[ \frac{\partial^2 L}{\partial m^2} < 0, \quad \frac{\partial^2 L}{\partial (\rho F)^2} < 0, \quad \frac{\partial^2 L}{\partial m \partial (\rho F)} > 0. \]

\textsuperscript{1/} See Boyer and Kingston (1986) for the use of the cash-in-advance constraint as a microeconomic foundation for currency substitution. Similarly, Greenwood and Kimbrough (1987) motivate the existence of a parallel currency market with a cash-in-advance requirement that forces individuals to accumulate foreign currency (either officially or illegally) before they can consume. Boyer and Kingston, however, assume "separable" constraints; that is, in this framework, they assume that the legally imported good can only be bought with domestic currency, and the smuggled good only with foreign currency. Separate cash-in-advance constraints are a particularly restrictive assumption for developing countries. If the only reason for dealing in foreign currency is to buy imported goods, the sole purpose of black market activity would be to enable smuggling.

\textsuperscript{2/} Strictly speaking, in discrete time the approximation to the Calvo-Végh (1990) liquidity-in-advance constraint would require using beginning-of-period stocks in equation (4). The formulation used here is, however, more convenient analytically.

\textsuperscript{3/} The assumption on the cross derivative of \( L \) rules out perfect substitutability between domestic and foreign currencies, and therefore eliminates corner solutions.
To simplify the algebra somewhat, it will be assumed that the consumer's instantaneous utility is a separable, logarithmic function, and that the liquidity services function is of the Cobb-Douglas form, therefore constraining to unity the elasticity of substitution between domestic and foreign currency:

$$V(c_t, \tilde{c}_t) = \log c_t + \log \tilde{c}_t,$$

(5)

$$L(m_t, \rho_F^t \rho_t) = (m_t)^\delta (\rho_F^t \rho_t)^{1-\delta}. \quad 0 \leq \delta \leq 1$$

(6)

The consumer chooses an optimal sequence \((c_t, \tilde{c}_t, m_t, b_t, b^*_t, F^t)\) to maximize (1) subject to (2)-(6). Assuming that equation (4) holds with equality, the optimality conditions for this control problem yield the following solution for the composition of money holdings: 1/

$$\frac{m_t}{\rho_F^t \rho_t} = \left(\frac{\delta}{1 - \delta}\right) \left(\frac{i^*_t}{(1 - \epsilon_{t+1})i_t}\right).$$

(7a)

and,

$$(1 - \epsilon_{t+1})i_t = (i^*_t + \Delta \rho_{t+1}(1 + \epsilon_{t+1})/\rho_t + \epsilon_{t+1}).$$

(7b)

When \(\epsilon_{t+1} = 0\) (that is, under fixed exchange rates), equations (7a) and (7b) become:

$$\frac{m_t}{\rho_F^t \rho_t} = [(1 - \delta)/\delta](i^*_t/i_t),$$

(7a')

$$i_t = (i^*_t + \Delta \rho_{t+1})/\rho_t.$$  

(7b')

Consider first equations (7a') and (7b'). Essentially, equation (7a') defines a demand function for the currency ratio \(m_t/\rho_F t\rho_t\), which inversely relates the marginal rate of substitution between domestic and foreign currencies to the ratio of their opportunity costs. Equation (7b') represents an interest parity condition that has been used in several models of dual exchange markets, notably the continuous-time models of Obstfeld (1986) and Bhandari and Végh (1990). It implies that an expected future depreciation of the domestic currency in the parallel market for foreign exchange would cause domestic residents to shift out of domestic money into foreign money, and vice versa. Equations (7a) and (7b) generalize (7a') and (7b') so as to account for fluctuations in the official exchange rate.

1/ A complete characterization of the solution procedure is given in Appendix I.
By substituting the interest parity condition (7b) in equation (7a), the domestic interest rate can be eliminated—a procedure that will prove particularly useful at the estimation stage, because of the lack of suitable data on market-determined rates in developing countries.

2. Adjustment costs and actual currency holdings

The desired, or "long-run", composition of currency holdings given by equations (7a) and (7b) can be written as, using the definition of $\rho_t$, 1/

$$q_t^d = \log(M_t/s_t F_t) = \kappa_0 + \kappa_1 z_t, \quad \kappa_1 > 0 \quad (7')$$

where $z_t = \log(i_t^*/((i_t^* + \Delta \rho_{t+1}(1 + \epsilon_{t+1}))/\rho_t + \epsilon_{t+1}))$, using the interest parity condition (7b). 2/

Following the "buffer stock" approach of Cuthbertson and Taylor (1987, 1990), we assume that agents pursue their currency ratio target subject to the costs of being out of long-run equilibrium and the costs of adjustment in currency holdings. 3/ These costs of adjustment may be thought of as costs incurred during reallocation of the individual's monetary portfolio, and may result, for instance, from the existence of regulations that restrict possibilities to acquire foreign exchange through official channels, or from restrictions on transfers of funds abroad. Formally, therefore, the representative agent undertakes a two-stage decision process. First, he determines the desired path of the currency ratio, $\{q_t^d\}_{k=0}^\infty$, and then makes an

1/ Note that this formulation abstracts from institutional and structural factors, such as the transaction costs incurred in the exchange of currencies (including the probability of being caught in fraudulent transactions), or the degree of diversification of the domestic financial system, that may influence the currency ratio. These factors would be indirectly reflected in the size of the coefficient $\kappa_1$.

2/ It can be shown that by using a CES liquidity function (instead of the Cobb-Douglas formulation given in equation (6)), the more general restriction $\kappa_1 > 0$ (instead of $\kappa_1 = 1$) would hold.

3/ For a critical evaluation of the Cuthbertson-Taylor forward-looking model of buffer stock money, see Muscatelli (1988) and Swamy and Tavlas (1989).
independent decision concerning the speed of adjustment toward this path. 1/

Agents choose the short-run currency ratio so as to minimize the expected discounted present value of a quadratic loss function, \( L \), conditional on information available at time \( t-1 \): 2/

\[
L = E_{t-1} \sum_{k=0}^{\infty} \gamma^k [\alpha_0 (q_{t+k} - q_{t+k}^d)^2 + \alpha_1 (q_{t+k} - q_{t+k-1})^2],
\]

where \( \alpha_i \) are positive weights and \( E_{t-1} \) denotes the conditional expectation operator for information up to time \( t-1 \). The actual currency ratio, \( q_t \), is chosen so as to minimize \( (8) \), for \( k = 0, 1, 2, \ldots \). The solution to this optimization problem is provided in Appendix I. It is given by:

\[
E_{t-1}q_t = \lambda_1 q_{t-1} + (1 - \lambda_1)(1 - \gamma \lambda_1) \sum_{j=0}^{\infty} (\gamma \lambda_1)^j E_{t-1}q_{t+j},
\]

where \( 0 < \lambda_1 < 1 \) is the stable root of the Euler equation obtained from the first-order conditions. Using \( (7'' \), and \( (9) \), the equation describing the behavior of the actual currency ratio is therefore given by:

\[
q_t = (1 - \lambda_1)\kappa_0 + \lambda_1 q_{t-1} + (1 - \lambda_1)(1 - \gamma \lambda_1)\kappa_1 \sum_{j=0}^{\infty} (\gamma \lambda_1)^j E_{t-1}z_{t+j} + \nu_t,
\]

where \( \nu_t \) denotes a random disturbance.

Equation (10) shows that the currency ratio depends on a backward-looking component, \( q_{t-1} \), and forward-looking variables—a geometrically-declining weighted sum of the opportunity-cost variable. A 1 percent increase in \( z_t \) in the current period and all future periods, for example, leads to an immediate rise in the currency ratio of \( (1 - \lambda_1)(1 - \gamma \lambda_1)\kappa_1 \) per cent, which thereafter continues to rise gradually—due to the existence of adjustment costs—to its new desired path. If the opportunity-cost variable \( z_t \) is generated by a random walk process, then the forward-looking model described by equation (10) reduces to a form that is of the partial adjustment (or adaptive expectations) variety (Nickell, 1985).

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1/ It is assumed here that the second stage decision does not affect the first stage decision by altering wealth and hence consumption.

2/ For a more general loss function, see Pesaran (1991).
IV. Econometric Methodology and Estimation Results

This section first describes the estimation procedure and then discusses the results obtained from estimation of equation (10). As noted in Section II, one needs to recognize several shortcomings and limitations in the data. The definition of "foreign money balances" in a currency substitution framework may cover several components, such as foreign currency deposits held in the domestic financial system, foreign money held abroad by domestic residents, and foreign currency notes circulating domestically. Data on all three components are extremely difficult to obtain for any country. Moreover, even when it is possible to isolate, say, foreign currency deposits in the domestic financial system, it is not always possible to identify whether the deposits are held by foreigners or by domestic residents. 1/ A particularly important source of error in the measurement of foreign money balances relates to the amount of foreign currency notes held by the public (in this case, domestic residents) in the country. The quantitative importance of this component is extremely difficult to estimate--especially in a country where parallel currency markets are important. 2/ As indicated in the Introduction, we focus here on residents' holdings of foreign currency deposits held in foreign banks abroad. Such a procedure does not take into account foreign currency deposits held in domestic banks and domestic nonbank foreign money balances. Accordingly, this measure will underestimate the magnitude of currency substitution if residents hold significant foreign currency deposits in domestic banks and if a significant portion of financial transactions in foreign currency takes place outside the formal banking system. 3/

1. Estimation method

To estimate equation (10), multi-step ahead predictions for the determinants of the currency ratio must be derived. Several alternative procedures can be used for modeling the expectational

1/ The bulk of those deposits are usually thought to be held by domestic residents, but this possible source of mispecification has to be kept in mind.

2/ Melvin (1988), for instance, has attempted to estimate the amount of U.S. dollars in circulation in Bolivia, but his procedure does not seem applicable to many of the countries considered here.

3/ Note also that the measures of domestic and foreign currency holdings used below for estimation include holdings of firms as well as households, while the theoretical model developed earlier pertains only to consumer money demand. The lack of data on business currency holdings prevented us from appropriately adjusting for this component.
terms appearing in the model. These procedures can be conveniently grouped into two classes: "substitution" methods, and "errors-in-variables" techniques. In the first case, the unknown future expectations entering the equation to be estimated are replaced by generated or predicted values derived from a forecasting equation for the driving process. This gives rise to the "generated regressors" situation, which has been extensively analyzed by Pagan (1984). In this paper, we use the errors-in-variables technique suggested by Wickens (1982, 1986).

Another problem that needs to be handled when estimating equation (10) is the existence of nonlinearities introduced by the presence of the discount factor $\gamma$ in several terms. In principle, estimation of the model in a restricted form would require the use of nonlinear least squares. Instead, the model is here estimated in an unrestricted form and the parameter constraints imposed by the rational expectations assumption are tested for three different values of $\gamma$ (0.1, 0.5, and 1.0), avoiding therefore the complications that would result from the application of a nonlinear estimation procedure. The restrictions result from the geometric term $(\gamma \lambda_1)^j$, which appears in the coefficients attached to the successive future expected values of the opportunity-cost variable $z$. Given the estimated value of $\lambda_1$ obtained from the coefficient on $q_{t-1}$ in (10), these parameter restrictions (also known as "backward-forward" restrictions) are tested using a Wald test.

1/ Pagan establishes the asymptotic equivalence of two-step and maximum likelihood estimates under certain conditions. He also shows that ordinary least squares applied to the second-stage equation may produce inconsistent estimates of standard errors and lead to invalid inferences--a point often overlooked in the empirical literature.

2/ In the application of this technique below, we do not account for the moving average property of the error process, which results from the errors-in-variables transformation (see Wickens, 1982, 1986, and Cuthbertson, 1990). Our estimates, although not fully efficient, are nevertheless consistent. Other limited-information methods (such as the Generalized IV technique or the Generalized 2SLS procedure discussed by Cuthbertson, 1990) are only asymptotically efficient and are of limited appeal, considering the sample size used here.

3/ Let $\mu_j = (1 - \lambda_1)(1 - \gamma \lambda_1)^j$ denote the estimated coefficient on $z_{t+j}$, where $j \geq 0, \ldots, n$. Let $\lambda_1$ denote the estimated parameter on $q_{t-1}$. The backward-forward restrictions are given by the $n$ relationships:

$$\mu_0 / \mu_j = 1 / (\gamma \lambda_1)^j, \quad j = 1, \ldots, n$$
2. Empirical results

Using the econometric procedure described above, the model described by equation (10) was estimated for ten developing countries: Bangladesh, Brazil, Ecuador, Indonesia, Malaysia, Mexico, Morocco, Nigeria, Pakistan and the Philippines. Data are quarterly and seasonally unadjusted for the period 1981:4 to 1991:2. Seasonal dummies were included in all regressions but are omitted in the Tables for convenience.

Table 2 presents unrestricted estimates for the parameters of equation (10). We initially experimented with up to four leads on the expectational variable $z_t$ for each country, and then "tested down" until an adequate specification was found. The results indicate that the model performs fairly well for most countries. The coefficient of determination is relatively low only for Malaysia, indicating that the regression accounts for a sizable fraction of the variance of the currency ratio for the other countries. The Lagrange multiplier ($\ell m$) test statistic indicates the absence of autocorrelation of the residuals in all cases. With the exception of Mexico, there is no evidence of departure from normality of the residuals, as shown by the Jarque-bera ($JQ$) test statistic, and evidence of (autoregressive conditional) heteroscedasticity seems to appear only for Bangladesh. The predictive Chow test, which examines the ex ante forecasting capability of the model over the period 1988:4-1990:1 indicates parameter instability only for Morocco, and only at a 5 percent significance level. Finally, for three countries--Brazil, Malaysia and Mexico--there is no evidence of expectational effects beyond a quarter ahead, suggesting for these economies a fairly short horizon.

1/ Data on foreign currency deposits held abroad were obtained from International Financial Statistics (IFS, line 7xrd), published by the Fund. The domestic money stock is measured by narrow money (IFS line 34). The "world" interest rate is measured by the three-month Eurodollar rate quoted in London (IFS line 60d for the U.K.).

2/ See Harvey (1990) for a description of the diagnostic tests reported in Tables 2 and 4.

3/ In some cases examined here, adding expectational terms for periods further ahead produced problems of multicollinearity. In other cases, longer-term expectations appeared statistically insignificant.

3/ The ability of the estimated currency ratio equation to generate good out-of-sample predictions represents an important diagnostic test for the hypothesis of parameter stability. Persistent out-of-sample overprediction of the currency ratio for instance, would tend to indicate the occurrence of a shift in the underlying relationship.
and/or a very high discount rate. Interestingly enough, Brazil and Mexico are countries that have experienced considerable macroeconomic instability over the estimation period, a phenomenon which has often been viewed as conducive to a high degree of substitution between domestic and foreign currencies.

Wald test statistics for the validity of the parameter restrictions imposed by rational expectations are shown in Table 3, for $\gamma = 0.1$, $\gamma = 0.5$ and $\gamma = 1.0$. The results indicate, first, that the effect of varying the value of $\gamma$ on the reported test statistics is negligible. Second, they also indicate that in no cases are the restrictions rejected at a 5 percent significance level, while they are rejected for only one country (Malaysia) at a 10 percent significance level.

Since the restrictions imposed by rational expectations cannot be rejected, the unrestricted parameters can be used to estimate the long-run elasticity of the currency ratio with respect to the opportunity cost variable, $\kappa_1$. The estimated value of $\kappa_1$, together with its approximate $t$-value, are shown at the bottom of Table 2. This elasticity is calculated by setting $z_t = z_{t+1} = \ldots$ in the regression equation and dividing the parameter sum by 1 minus the coefficient on the lagged currency ratio, as implied by equation (10). The results indicate that the long-run elasticity coefficients are significant and in the expected range (except perhaps for Nigeria, which seems to be on the low side) and are statistically significant at conventional levels, except for Malaysia.

Unit root tests and cointegration tests between the currency ratio, $q$, and the opportunity cost ratio, $z$, were also conducted. The results, given in Appendix II, show identical orders of integration for these variables in the majority of cases. Following Cuthbertson and Taylor (1990), it can be shown that estimation of the forward-looking model developed here is tantamount to estimation of an error-correction representation. Thus similar estimates of the long-run parameters should be observed from cointegration analysis by the Granger Representation Theorem (Engle and Granger, 1987).

3. Comparison with a conventional model

For comparison purposes, a "conventional" partial adjustment model of the currency ratio was also estimated. The conventional formulation here relates the currency ratio to its lagged value and

1/ The estimated value of $\kappa_1$ may lack efficiency because unrestricted parameters estimates are used and because the infinite sum appearing in (10) is truncated.
Table 2. Estimation Results: Forward-Looking Model
(Errors-in-variables/instrumental variables procedure)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Bangladesh</th>
<th>Brazil</th>
<th>Ecuador</th>
<th>Indonesia</th>
<th>Malaysia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>1.478</td>
<td>0.396</td>
<td>0.321</td>
<td>0.186</td>
<td>0.793</td>
</tr>
<tr>
<td></td>
<td>(2.131)</td>
<td>(1.729)</td>
<td>(1.527)</td>
<td>(1.159)</td>
<td>(2.221)</td>
</tr>
<tr>
<td>$q_{t-1}$</td>
<td>0.431</td>
<td>0.915</td>
<td>1.132</td>
<td>0.891</td>
<td>0.587</td>
</tr>
<tr>
<td></td>
<td>(1.496)</td>
<td>(10.563)</td>
<td>(8.745)</td>
<td>(4.051)</td>
<td>(2.408)</td>
</tr>
<tr>
<td>$z_{t}$</td>
<td>-0.145</td>
<td>-0.348</td>
<td>-0.018</td>
<td>0.439</td>
<td>-4.103</td>
</tr>
<tr>
<td></td>
<td>(-1.193)</td>
<td>(-1.504)</td>
<td>(-0.082)</td>
<td>(0.331)</td>
<td>(-0.699)</td>
</tr>
<tr>
<td>$z_{t+1}$</td>
<td>0.026</td>
<td>0.544</td>
<td>-0.623</td>
<td>0.821</td>
<td>4.906</td>
</tr>
<tr>
<td></td>
<td>(0.017)</td>
<td>(1.813)</td>
<td>(-1.506)</td>
<td>(2.934)</td>
<td>(1.733)</td>
</tr>
<tr>
<td>$z_{t+2}$</td>
<td>0.381</td>
<td>---</td>
<td>0.661</td>
<td>-1.523</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>(2.190)</td>
<td>(1.557)</td>
<td>(-0.547)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$z_{t+3}$</td>
<td>-0.498</td>
<td>---</td>
<td>-0.801</td>
<td>-0.279</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>(-0.779)</td>
<td>(-2.117)</td>
<td>(-0.667)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$z_{t+4}$</td>
<td>1.186</td>
<td>---</td>
<td>---</td>
<td>0.996</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>(1.659)</td>
<td>(2.507)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$R^2$     0.892  0.797  0.871  0.927  0.384
$\sigma$  0.219  0.153  0.156  0.078  0.196
$ln(\theta)$ 0.0138 1.326  0.725  0.207  1.146
$arch(8)$ 2.493  1.012  0.546  0.223  1.075
$JQ$      0.739  0.119  1.094  1.753  0.701
$Chow$    0.241  1.197  0.375  1.954  0.947

$\kappa_1$ 1.669  2.341  ---  4.165  1.944
           (1.907) (6.003) (1.930) (1.297)

Notes: Estimation period is 1982:4-1990:1. Instruments are 4 lags of $q$ and $z$, seasonal dummies and the constant term. $R^2$ denotes the adjusted coefficient of determination, $\sigma$ the estimated standard error of the regression, $JQ$ the Jarque-Bera normality test statistic, and $ln(n)$ is the Lagrange Multiplier test statistic for serial correlation in the residuals of order up to $n$. $arch(n)$ is the Engle test statistic for autoregressive conditional heteroscedasticity of order up to $n$. $Chow$ denotes the Chow predictive failure test over 1988:4-1990:1. Numbers in parentheses denote $t$-statistics. A "---" indicates that the parameter is set to zero or is not defined.
Table 2 (concluded). Estimation Results: Forward-Looking Model  
(Errors-in-variables/instrumental variables procedure)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mexico</th>
<th>Morocco</th>
<th>Nigeria</th>
<th>Pakistan</th>
<th>Philippines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-0.042</td>
<td>0.389</td>
<td>-0.113</td>
<td>0.183</td>
<td>0.151</td>
</tr>
<tr>
<td></td>
<td>(-0.247)</td>
<td>(1.387)</td>
<td>(-0.662)</td>
<td>(1.227)</td>
<td>(1.736)</td>
</tr>
<tr>
<td>$q_{t-1}$</td>
<td>0.869</td>
<td>0.804</td>
<td>0.364</td>
<td>0.877</td>
<td>0.759</td>
</tr>
<tr>
<td></td>
<td>(8.157)</td>
<td>(4.809)</td>
<td>(1.906)</td>
<td>(9.665)</td>
<td>(5.213)</td>
</tr>
<tr>
<td>$z_t$</td>
<td>-0.273</td>
<td>-1.151</td>
<td>-0.405</td>
<td>0.112</td>
<td>0.103</td>
</tr>
<tr>
<td></td>
<td>(-0.347)</td>
<td>(-1.165)</td>
<td>(-1.224)</td>
<td>(0.316)</td>
<td>(0.764)</td>
</tr>
<tr>
<td>$z_{t+1}$</td>
<td>1.081</td>
<td>-0.239</td>
<td>0.158</td>
<td>-0.016</td>
<td>-0.610</td>
</tr>
<tr>
<td></td>
<td>(1.813)</td>
<td>(-0.782)</td>
<td>(0.263)</td>
<td>(-0.035)</td>
<td>(-0.816)</td>
</tr>
<tr>
<td>$z_{t+2}$</td>
<td>---</td>
<td>1.766</td>
<td>0.448</td>
<td>0.287</td>
<td>0.834</td>
</tr>
<tr>
<td></td>
<td>(-2.481)</td>
<td>(1.991)</td>
<td>(1.833)</td>
<td>(2.870)</td>
<td></td>
</tr>
<tr>
<td>$z_{t+3}$</td>
<td>---</td>
<td>---</td>
<td>-0.245</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(-0.319)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$z_{t+4}$</td>
<td>---</td>
<td>0.624</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(2.362)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.748</td>
<td>0.756</td>
<td>0.796</td>
<td>0.839</td>
<td>0.689</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>0.157</td>
<td>0.087</td>
<td>0.153</td>
<td>0.079</td>
<td>0.141</td>
</tr>
<tr>
<td>$\ln(n)$</td>
<td>0.034</td>
<td>0.041</td>
<td>0.113</td>
<td>0.064</td>
<td>0.453</td>
</tr>
<tr>
<td>arch(n)</td>
<td>0.088</td>
<td>0.493</td>
<td>1.117</td>
<td>0.481</td>
<td>0.974</td>
</tr>
<tr>
<td>JQ</td>
<td>7.159</td>
<td>0.809</td>
<td>0.359</td>
<td>1.641</td>
<td>1.503</td>
</tr>
<tr>
<td>Chow</td>
<td>0.531</td>
<td>2.197</td>
<td>1.473</td>
<td>0.263</td>
<td>0.065</td>
</tr>
</tbody>
</table>

Notes: Estimation period is 1982:4-1990:1. Instruments are 4 lags of q and z, seasonal dummies and the constant term. $R^2$ denotes the adjusted coefficient of determination, $\sigma$ the estimated standard error of the regression, JQ the Jarque-Bera normality test statistic, and $\ln(n)$ is the Lagrange Multiplier test statistic for serial correlation in the residuals of order up to n. arch(n) is the Engle test statistic for autoregressive conditional heteroscedasticity of order up to n. Chow denotes the Chow predictive failure test over 1988:4-1990:1. Numbers in parentheses denote t-statistics. A "---" indicates that the parameter is set to zero or is not defined.
Table 3. Test Statistics for Backward-Forward Restrictions

<table>
<thead>
<tr>
<th>Country</th>
<th>Restrictions</th>
<th>Discount factor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$\gamma = 0.1$</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>4</td>
<td>0.382</td>
</tr>
<tr>
<td>Brazil</td>
<td>1</td>
<td>1.657</td>
</tr>
<tr>
<td>Ecuador</td>
<td>3</td>
<td>10.829</td>
</tr>
<tr>
<td>Indonesia</td>
<td>4</td>
<td>1.879</td>
</tr>
<tr>
<td>Malaysia</td>
<td>1</td>
<td>1.486</td>
</tr>
<tr>
<td>Mexico</td>
<td>1</td>
<td>1.117</td>
</tr>
<tr>
<td>Morocco</td>
<td>2</td>
<td>1.756</td>
</tr>
<tr>
<td>Nigeria</td>
<td>4</td>
<td>0.751</td>
</tr>
<tr>
<td>Pakistan</td>
<td>2</td>
<td>0.681</td>
</tr>
<tr>
<td>Philippines</td>
<td>2</td>
<td>0.765</td>
</tr>
</tbody>
</table>

Notes: The backward-forward restrictions are tested using a Wald test statistic, which is distributed asymptotically as $\chi^2(m)$, where $m$ is the number of restrictions. The critical values for rejection of the null hypothesis are, for 1, 2, 3, and 4 restrictions, 3.84, 5.99, 7.82 and 9.49, respectively, at a 5 percent significance level, and 2.71, 4.61, 6.25 and 7.78, respectively, at a 10 percent significance level.
negatively to the current rate of depreciation of the parallel market exchange rate, \( \log(s_t/s_{t-1}) \), or equivalently, 1/

\[
q_t = \alpha_0 + \alpha_1 \log(s_{t-1}/s_t) + \alpha_2 q_{t-1}.
\] (11)

A conceptually similar formulation has been used in the context of analytical work on dual exchange markets by Lizondo (1987) and Kharas and Pinto (1989). 2/ Estimation results for equation (11) appear in Table 4. Although the adjusted coefficient of determination seems significantly higher in several cases (Mexico, Nigeria, Pakistan, and the Philippines) than what obtains for the forward-looking estimates reported in Table 2; other test statistics are more favorable to the latter formulation. In Table 4, the Lagrange Multiplier test statistic indicates the presence of autocorrelated residuals in five countries (Ecuador, Indonesia, Mexico, Nigeria and Pakistan), and there is evidence of departure from normality of the error term in four cases (Brazil, Morocco, Nigeria and Pakistan). Heteroscedasticity also seems to be present in the estimation results for Morocco and Nigeria. The predictive Chow test indicates parameter instability for Brazil, Ecuador, Indonesia, Mexico, Morocco, Nigeria, and (to a lesser extent) the Philippines. Finally, coefficients on the lagged endogenous variable are substantially higher than those estimated with the forward-looking model for several countries—a result that indicates an implausibly slow speed of adjustment and implausible long-run elasticities.

1/ The expected return on holdings of foreign assets could be measured by the sum of the rate of depreciation of the parallel market exchange rate and the foreign inflation rate, as in Taylor and Phylaktis (1991), who found evidence that such a variable affects the demand for money in high-inflation economies during the 1970s and 1980s (Argentina, Bolivia, Brazil, Chile, and Peru).

2/ In the currency-substitution literature, the expected rate of depreciation of the domestic currency has often been approximated by deviations from purchasing power parity, with foreign prices valued at the parallel market rate; see, for example, Blejer (1978), and Fasano-Filho (1986). Ramírez-Rojas (1985), in his estimates for Argentina and Mexico, uses the (current) differential between the domestic and the "world" inflation rates to approximate the expected rate of change of the exchange rate. For Mexico, he also uses the three-month future price of the U.S. dollar in Pesos, while for Uruguay, he uses the differential between the domestic interest rate paid on deposits denominated in domestic currency and the domestic interest rate paid on foreign currency deposits. The last proxy can perform well only when domestic rates are freely determined by the market.
A more formal comparison between the forward-looking optimizing model (10) and the conventional formulation (11) can be implemented by using the non-nested PE procedure of MacKinnon et al. (1983)—a test that is easy to compute and has intuitive appeal. Estimation results are reported in Table 5. The significant statistical effect of the difference between the predictions of the forward-looking and conventional models in the prediction error of the conventional model suggests in all but one case (Malaysia) that the forward-looking model can help improve the forecasts produced by the conventional model (see the first column of Table 5). By contrast, as indicated in the second column of Table 5, prediction errors from the conventional model help to improve the predictive capacity of the forward-looking model in only four cases (Mexico, Morocco, Nigeria, and the Philippines)—a result that does not hold at the 1 percent significance level for two of the countries (Mexico and Nigeria).

The general implication of the above results is that both direct (regression diagnostic tests) and indirect (non-nested tests) statistical evidence suggest that the forward-looking model performs better than a conventional partial adjustment model for most countries in the sample. Given that the forward-looking model is rigorously derived from an optimizing framework, that it embodies theoretical restrictions on its parameters, and that it provides an adequate representation of the data, it can be viewed as a plausible alternative to the more conventional partial adjustment model.

---

1/ The non-nested test of MacKinnon et al. (1983), can briefly be presented as follows. Suppose one is interested in testing two alternative model specifications for the variable \( y_t \):

\[
H_0: \quad y_t = \alpha_0 + \sum_i x_{it} + u_t, \quad H_1: \quad y_t = \alpha_0 + \sum_i z_{it} + v_t,
\]

where the \( x_i \) and \( z_i \) are two (generally different) sets of exogenous variables. Denoting by \( \tilde{y}_t^0 \) and \( \tilde{y}_t^1 \), the predicted values of the dependent variables under \( H_0 \) and \( H_1 \), respectively, the PE tests of \( H_0 \) and \( H_1 \) are the tests of \( \alpha = 0 \) in:

\[
y_t - \tilde{y}_t^0 = \alpha_0 + \sum_i x_{it} + \alpha(\tilde{y}_t^1 - \tilde{y}_t^0) + \epsilon_t,
\]

and,

\[
y_t - \tilde{y}_t^1 = \alpha_0 + \sum_i z_{it} + \alpha(\tilde{y}_t^0 - \tilde{y}_t^1) + \epsilon_t.
\]

In both equations, the \( t \)-ratio corresponding to the OLS estimate of \( \alpha \) is asymptotically distributed as \( N(0,1) \) under the tested hypothesis. In effect, the test of one model uses specific information about the non-nested alternative in its construction. For a further discussion, see Gregory and McAleer (1983).
Table 4. Estimation Results: Conventional Model
(Instrumental variables procedure)

<table>
<thead>
<tr>
<th>Country</th>
<th>$a_0$</th>
<th>$\log(s_{t-1}/s_t)$</th>
<th>$q_{t-1}$</th>
<th>$R^2$</th>
<th>$\hat{\sigma}$</th>
<th>$\ln(n)$</th>
<th>$\text{arch}(n)$</th>
<th>JQ</th>
<th>Chow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangladesh</td>
<td>0.081</td>
<td>0.397</td>
<td>0.991</td>
<td>0.941</td>
<td>0.191</td>
<td>0.784</td>
<td>0.903</td>
<td>0.859</td>
<td>1.373</td>
</tr>
<tr>
<td></td>
<td>(1.051)</td>
<td>(0.665)</td>
<td>(19.548)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brazil</td>
<td>0.729</td>
<td>0.349</td>
<td>0.788</td>
<td>0.886</td>
<td>0.144</td>
<td>1.102</td>
<td>0.221</td>
<td>8.947</td>
<td>2.160</td>
</tr>
<tr>
<td></td>
<td>(2.773)</td>
<td>(1.697)</td>
<td>(9.294)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ecuador</td>
<td>0.094</td>
<td>1.026</td>
<td>0.947</td>
<td>0.969</td>
<td>0.076</td>
<td>8.544</td>
<td>0.474</td>
<td>1.663</td>
<td>3.552</td>
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<td>(4.102)</td>
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<td>0.893</td>
<td>0.873</td>
<td>0.151</td>
<td>9.143</td>
<td>0.487</td>
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<td>(7.251)</td>
<td>(29.828)</td>
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<td>Morocco</td>
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<td>0.989</td>
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<td>(2.091)</td>
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<td>Philippines</td>
<td>0.132</td>
<td>0.997</td>
<td>0.927</td>
<td>0.857</td>
<td>0.096</td>
<td>1.822</td>
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<td>0.771</td>
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<td>(2.407)</td>
<td>(10.723)</td>
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Notes: Estimation period is 1982:4-90:1. Instruments are 4 lags of $q$ and $\log(s_{t-1}/s_t)$, seasonal dummies and the constant term. $R^2$ denotes the adjusted coefficient of determination, $\hat{\sigma}$ the estimated standard error of the regression. JQ the Jarque-Bera normality test statistic, and $\ln(n)$ is the Lagrange Multiplier test statistic for serial correlation in the residuals of order up to $n$. Arch($n$) is Engle's test statistic for autoregressive conditional heteroskedasticity of order up to $n$. Chow denotes the Chow predictive failure test statistic, over 1988:4-90:1. Numbers in parentheses denote $t$-statistics. A "---" indicates that the parameter is set to zero or is not defined.
Table 5. Non-Nested Test Statistics

<table>
<thead>
<tr>
<th>Country</th>
<th>Conventional model 1/</th>
<th>Forward-looking Model 2/</th>
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<tbody>
<tr>
<td>Bangladesh</td>
<td>8.281</td>
<td>1.075</td>
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<tr>
<td>Brazil</td>
<td>3.879</td>
<td>-0.904</td>
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<tr>
<td>Ecuador</td>
<td>7.495</td>
<td>1.177</td>
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<td>Indonesia</td>
<td>9.965</td>
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<td>Malaysia</td>
<td>0.180</td>
<td>0.397</td>
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<td>Mexico</td>
<td>11.771</td>
<td>1.734</td>
</tr>
<tr>
<td>Morocco</td>
<td>4.327</td>
<td>2.269</td>
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<tr>
<td>Nigeria</td>
<td>5.509</td>
<td>1.869</td>
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<td>Pakistan</td>
<td>9.677</td>
<td>0.473</td>
</tr>
<tr>
<td>Philippines</td>
<td>2.640</td>
<td>-2.039</td>
</tr>
</tbody>
</table>

Notes: Estimation period is 1982:4-1990:1. The statistic for the non-nested test is a t-ratio corresponding to the OLS estimate of $\alpha$, which is asymptotically distributed as $N(0,1)$ under the null hypothesis. The test is two-sided, so that a significant test statistic leads to rejection of the tested model, while an insignificant value does not lead to rejection. For a sample size equal to 30, the critical values for rejection of the null hypothesis are approximately 1.65 and 2.58 at the 5 and 1 percent significance levels, respectively.

1/ Test for the addition of $(\hat{q}_t^F - \hat{q}_t^C)$ in equation (11), with $(q_t - \hat{q}_t^C)$ as the dependent variable. The predicted values of the forward-looking and conventional models are $\hat{q}_t^F$ and $\hat{q}_t^C$, respectively.

2/ Test for the addition of $(\hat{q}_t^C - \hat{q}_t^F)$ in equation (10), with $(q_t - \hat{q}_t^F)$ as the dependent variable. The predicted values of the forward-looking and conventional models are $\hat{q}_t^F$ and $\hat{q}_t^C$, respectively.
IV. Conclusions

The purpose of this paper has been to derive and test a currency substitution model in which portfolio decisions depend upon forward-looking variables. The long-run, or equilibrium, currency ratio is derived from an optimizing model in which agents can hold domestic and foreign currencies, as well as domestic and foreign bonds. The actual currency ratio is derived in a framework that is based on a multi-period cost of adjustment scheme, involving rational forward-looking expectations. Empirical implementation of the model for ten developing countries has proven encouraging. The forward-looking model had statistically significant coefficients as implied by the theory, and the forecasting ability of the model appeared satisfactory. Basically, a substantial amount of the variation in the ratio of domestic to foreign money balances is accounted for by changes in foreign interest rates and in the premium in the parallel exchange market. A formal comparison of the forward-looking formulation with a conventional, partial-adjustment specification for the currency ratio, using a non-nested testing procedure, shows that the former model is to be preferred in almost all cases.

Aside from the use of a rational-expectations framework, two other important methodological and empirical features of the paper are worth mentioning. First, use is made of data on foreign currency deposits held abroad. Such data have not been employed before in the literature dealing with currency substitution in developing countries. Second, the model does not require information on domestic interest rates, which turns out to be an important advantage in the case of developing countries where data on market-based interest rates are generally lacking. In this sense the paper goes beyond other empirical studies of currency substitution.

It is useful to end by considering, in a general way, what policy options are available to governments to stem the rise in foreign currency deposits, and what actions can be taken to generate a possible reflow of financial wealth into domestic financial assets. Obviously, providing a stable financial and macroeconomic environment would go a long way toward this end. Adopting sound macroeconomic policies with the appropriate exchange rate and interest rates would seem to be a key element in reducing financial transfers abroad and the attendant problem this phenomenon creates for capital-scarce economies. Of course, it is highly unlikely that a government will be able to prevent all increases in foreign currency deposits even in the best of circumstances. What the authorities can do is to try and change existing incentives in the economy so as to minimize shifts in portfolios toward foreign currency deposits, and thereby direct more resources, both domestic and foreign, toward expanding the productive base of the economy.
APPENDIX I

Model Solutions

In this Appendix we first derive the necessary conditions for the optimal individual optimization problem described in equations (1)-(6). Let $\lambda^1_t$, $\lambda^2_t$ and $\lambda^3_t$ denote the Lagrange multipliers associated with, respectively, the portfolio constraint (2'), the flow constraint (3'), and the cash-in-advance constraint (4). Necessary conditions for optimality are found by maximizing the Lagrangian:

$$L = \sum_{t=0}^{\infty} \gamma^t \left( V(c_t, \tilde{c}_t) + \lambda^1_t[a_t - m_t - b_t - \rho_t(b^+_t + F_t)] \right) \quad (A1)$$

$$- \lambda^2_t[a_t - a_{t-1} - (1 + \sigma(\rho_t - 1))\theta - [i_{t-1} - \epsilon_t(1 + i_{t-1})]b_{t-1}$$

$$+ (c_t + \rho_t\tilde{c}_t) - [i^*_t + \Delta\rho_t(1 + \epsilon_t)]b^*_{t-1}$$

$$- \Delta\rho_t(1 + \epsilon_t)F_{t-1} + \epsilon_t^m_{t-1}$$

$$- \lambda^3_t[c_t + \rho_t\tilde{c}_t - (m_t)^{\delta}(\rho_tF_t)^{1-\delta}] \right),$$

with respect to $c_t$, $\tilde{c}_t$, $m_t$, $b_t$, $i^*_t$, $F_t$, and $a_t$, $\forall t$. This yields 1/:

$$V'(c_t) = 1/c_t = \lambda^2_t + \lambda^3_t, \quad (A2a)$$

$$V'(\tilde{c}_t) = 1/\tilde{c}_t = \rho_t(\lambda^2_t + \lambda^3_t), \quad (A2b)$$

$$\lambda^2_t(\rho_tF_t/m_t)^{1-\delta} = \lambda^1_t + \gamma\lambda_{t+1}^2\epsilon_{t+1}, \quad (A2c)$$

$$\gamma\lambda_{t+1}^2[i_t - \epsilon_{t+1}(1 + i_t)] = \lambda^1_t, \quad (A2d)$$

1/ In addition to equations (A2), the optimal solution must satisfy the lifetime resource constraint $\lim_{t \to \infty} (1 + \gamma)^{-\delta} a_t \geq 0$. Using equation (3'), this inequality can be written in a form that restricts the present value of spending on consumption and on the services of domestic and foreign real balances to the value of real wealth at the beginning of period 0.
First, note that from (A2a) and (A2b), $c_t = \rho_t \tilde{c}_t$, which yields, using (4)—holding exactly—$2c_t = L(m_t, \rho_t F_t)$. These equations determines the path of consumption once the composition of currency holdings is known. Second, note that from (A2d) and (A2e),

$$i_t - \epsilon_t (1 + i_t) = (1/\rho_t)[i_t^* + \Delta \rho_t (1 + \epsilon_t)],$$

which yields equation (7b) in the text.

From (A2e), we can substitute out for $\lambda_{t+1}^2$ in (A2c) and (A2f). Dividing the resulting expressions for (A2c) by (A2f) and using (A3) yields equation (7a) in the text.

Using equation (8), we now examine how short-run currency holdings are determined. The solution of this optimization problem follows Sargent (1987a, pp. 393–96). Necessary first-order conditions for minimization of (8), with respect to $q_t$ ($k=0,1,2,...$), are a set of stochastic Euler equations and a transversality condition, which are given by the following equations:

$$\gamma E_{t+k-1} q_{t+k+1} + \phi E_{t+k-1} q_{t+k} + q_{t+k-1} = -\alpha E_{t+k-1} q_{t+k},$$  

$$\lim_{T \to \infty} E_{t-1} \gamma [(\alpha_0 + \alpha_1) q_{t+T} - \alpha_1 q_{t+T-1} - \alpha_0 q_{t+T}] = 0,$$

where $\alpha = \alpha_0/\alpha_1$, and $\phi = -(1 + \alpha + \gamma)$. Equation (A4a) can be rewritten as

$$(1 + \phi \gamma^{-1} B + \gamma^{-1} B^2) E_{t+k-1} q_{t+k+1} = -(\alpha/\gamma) E_{t+k-1} q_{t+k}$$

where $B$ is the information-neutral backshift operator, defined such that $B^{-1} z_{t+k} = E_{t-1} z_{t+k+1}$. Factorizing the polynomial on the left-hand side of (A5) yields

$$(1 - \lambda_1 B)(1 - \lambda_2 B) = 1 - (\lambda_1 + \lambda_2) B + \lambda_1 \lambda_2 B^2 = 1 + \phi \gamma^{-1} B + \gamma^{-1} B^2.$$
Equating powers of $B$ gives $\phi = \lambda_1 \gamma + (1/\lambda_1)$ and $\lambda_2 = 1/\lambda_1 \gamma$.

Without loss of generality, assume that $\lambda_1 < \lambda_2$. As shown by Sargent (1987a, pp. 201-202), it can be established that $0 < \lambda_1 < 1 < 1/\gamma < \lambda_2$.

The solution to the Euler equations, which satisfies the transversality condition can be shown to be: 

\[
E_{t+k-1} q_{t+k} = \lambda_1 q_{t+k-1} + \alpha \gamma^{-1} \lambda_2^{-1} \sum_{j=0}^{\infty} (\lambda_2^{-1})^j E_{t+k-1} q_{t+k+j}^d. \tag{A7}
\]

Using the above relationship between $\lambda_1$ and $\lambda_2$, and setting $\tau = t+k$, (A7) can be written as

\[
E_{t+k-1} q_{\tau} = \lambda_1 q_{\tau-1} + (1 - \lambda_1)(1 - \gamma \lambda_1) \sum_{j=0}^{\infty} (\gamma \lambda_1)^j E_{t+k-1} q_{\tau+j}^d, \tag{A8}
\]

which corresponds to equation (9) in the text.

---

1/ To satisfy the transversality condition, we need, in fact, to impose some restrictions on the exponential orders of the sequences $\{q^e_t\}$ and $\{q^d_t\}$; see Sargent (1987a, p. 201).
In this Appendix we present unit root and cointegration tests for the currency ratio, \( q \), and the opportunity-cost ratio, \( z \). Cointegration analysis provides a testable definition of the long-run equilibrium that exists among non-stationary time series. \(^1\)

The tests for cointegration reported here follow the two-step procedure outlined in Engle and Granger (1987). The order of integration of each time series is first determined using an augmented Dickey-Fuller procedure. \(^1\) To test the null hypothesis that a series \( x_t \) is integrated of order one--I(1), or difference-stationary--the following equation is estimated using ordinary least squares:

\[
\Delta x_t = c_0 + c_1 x_{t-1} + \sum_{j=1}^{n} c_{j+1} \Delta x_{t-j} + u_t
\]

The null hypothesis is \( H_0: x_t \) is I(1), which is rejected in favor of I(0) if \( \hat{c}_1 \) is found to be negative and statistically significant. The conventionally calculated \( t \)-statistic for the estimated coefficient \( \hat{c}_1 \) can be used, although it does not follow the \( t \)-distribution under \( H_0 \). Critical values are taken from the tables compiled recently by Blangiewicz and Charemza (1990) for small samples. The parameter \( n \) is chosen so as to render the disturbance

\(^1\) Formally, a variable \( z \) is said to be integrated of order \( d \), denoted \( z_t \sim I(d) \), if the \( d \)th difference of \( z \) is stationary. Let \( Z_t \) be an \( n \times 1 \) vector of time series. The vector \( Z_t \) is said to be cointegrated of order \( d, p \), denoted \( Z_t \sim CI(d, p) \) if (i) each component of \( Z_t \) is integrated of order \( d \); and (ii) there exists a non-zero vector \( \alpha \) such that the linear combination \( \alpha'Z_t \) is integrated of order \( d - p \), for \( p > 0 \). Simply put, If the series \( q \) and \( z \) are non-stationary but some linear combination of them is a stationary process, then \( q \) and \( z \) are said to be co-integrated. A comprehensive treatment of the statistical theory of cointegration is given in Engle and Granger (1987) and Psaradakis (1989).

\(^1\) One important shortcoming of Dickey-Fuller (DF/ADF) procedures is the assumption of independent and identically distributed errors. Other methods which allow for weakly dependent and heterogeneously distributed error processes have recently been developed; see Pagan and Wickens (1989).
term $u_t$ approximately white, namely, serially uncorrelated residuals. For $n = 0$, the test procedure is referred to as the Dickey-Fuller (DF) test, while for $n > 1$, it is referred to as the Augmented Dickey-Fuller (ADF) procedure.

Table 6 presents estimates of the $t$-statistic for the coefficient $c_1$ (obtained by applying ordinary least squares (OLS) to equation B1) for all countries in the sample, together with the value of $n$ chosen on the basis of the above criterion. The null hypothesis that $q$ and $z$ are both I(1) is rejected at the 5 percent significance level by the DF/ADF test for all of the countries except Bangladesh, Indonesia, and Malaysia.

The second step of the procedure consists in estimating

$$q_t = \alpha_0 + \alpha_1 z_t + v_t,$$  \hspace{1cm} (B2)

and testing whether the residual series $\hat{v}_t$ is stationary. Stock (1987) has shown that the OLS estimate $\hat{c}_1$ is "superconsistent" in that it will have a finite sample bias of the order of $1/T$, $T$ being the sample size. 2/ If the residual series rejects the null of I(1), then the series used in (B2) are cointegrated. As suggested by the simulation analyses of Engle and Granger (1987), the augmented Dickey-Fuller procedure (equation B1) is also used here to perform the cointegration test.

DF/ADF test statistics for the three countries for which both $q$ and $z$ were found to be I(1) are -3.291 for Bangladesh (with $n = 0$), -0.413 for Indonesia (with $n = 4$) and -1.481 for Malaysia (with $n = 0$). Using the tables in Blandiewicz and Charemza (1990), it appears that at the 5 percent significance level, the null assumption of no cointegration (or unit root in the residual series $\hat{v}_t$) cannot be rejected for Indonesia and Malaysia—a country for which the estimate of the long-run parameter $\kappa_1$ was found to be statistically insignificant.

1/ For Brazil, Morocco, Pakistan and the Philippines, both variables are I(0)—a result which renders cointegration analysis meaningless.

2/ For I(0) variates, an estimator is considered consistent if it has finite sample bias of the order or $\sqrt{T}$.  

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Table 6. Unit Root Tests

<table>
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<tr>
<th>Country</th>
<th>n</th>
<th>DF/ADF Test Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangladesh q</td>
<td>0</td>
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<tr>
<td>Bangladesh z</td>
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<td>-1.613</td>
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<tr>
<td>Brazil q</td>
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<td>-3.173</td>
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<tr>
<td>Brazil z</td>
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<td>-3.754</td>
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<td>Ecuador q</td>
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<tr>
<td>Ecuador z</td>
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<td>Indonesia q</td>
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<td>Mexico z</td>
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<td>Morocco z</td>
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<td>Nigeria q</td>
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<td>Nigeria z</td>
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<td>Pakistan q</td>
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<td>Philippines z</td>
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<td>-3.057</td>
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</tbody>
</table>

**Notes:** Estimation period is 1982:1-1991:2, and sample size is 38. The null hypothesis is that the series in question is \( I(1) \). The approximate 1, 5, and 10 percent critical values for the DF test are -2.6, -1.9, and -1.6, respectively. The approximate values for the ADF test are -3.6, -2.8, and -2.4, respectively (Blangiewicz and Charemza, 1990, p. 306).
References


