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An Econometric Rational-Expectations Macroeconomic Model For Developing Countries with Capital Controls

Prepared by Nadeem U. Haque, Kajal Lahiri and Peter Montiel*

Authorized for Distribution by Mohsin S. Khan

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Abstract

A small macroeconomic model based on familiar theoretical considerations is developed and estimated using data from 31 developing countries. Efficient estimation techniques are used to control for country heterogeneity under the assumption of rational expectations. The estimates and the test statistics suggest that the model could serve well as a framework for developing-country macroeconomic analysis. An interesting feature of the specification of the model is that it allows the hypothesis of capital mobility to be explicitly tested. The empirical analysis suggests that on average developing countries tend to exhibit a high degree of capital mobility.

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*Kajal Lahiri, Professor of Economics at SUNY-Albany, was a Visiting Scholar in the Research Department when this paper was written. The authors are grateful to Mohsin Khan for helpful comments, and to Ravina Malkani for excellent research assistance.

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I. Introduction

Despite the increased attention that macroeconomic management in developing countries has received during the present decade, no consensus has emerged on the appropriate analytical framework for the study of developing-country macroeconomic issues. Instead, individual models suitable for different tasks have proliferated with different, and often conflicting, assumptions about a wide range of crucial aspects of these economies, such as the nature of financial markets, the degree of capital mobility, the form and functioning of the exchange-rate regime, the degree of wage-price flexibility, the determination of aggregate supply, the extent to which agents' expectations are forward-looking, and so on.

This lack of consensus on analytical macroeconomic models for developing countries turns out to be even more pronounced at the empirical level. Substantial disagreement exists over the general specification of such models, as well as orders of magnitude of certain key macroeconomic parameters--e.g., the interest responsiveness of saving and investment, the "offset coefficient" for monetary policy, the relative-price elasticity of exports and imports, and the importance of "accelerator" mechanisms in the determination of investment. While estimates of macroeconomic parameters such as these are available for developing countries, they differ greatly with regard to countries and periods covered, specifications of estimated equations, and--possibly most importantly--the empirical methodology employed in producing them. Consequently, generalizations across developing countries are virtually impossible to make.

The aim of this paper is to generate "representative" developing-country estimates of a set of macroeconomic parameters that are considered important for policy, utilizing a uniform data set for a relatively large group of countries and relying on appropriate empirical techniques to obtain these estimates. To do so, we construct a fairly simple macro-economic model using widely-accepted developing-country specifications for the key behavioral relationships wherever possible. The structural parameters are then estimated as a system.

Although the behavioral relationships in our model are conventional to some extent, our work differs from existing developing-country empirical macroeconomic models both in that we assume that expectations are formed rationally and agents are thus assumed to be forward looking, and in that we make explicit allowance for the presence of capital controls, the latter being a feature which, though pervasive in developing economies, is invariably neglected when it comes to empirical analysis.

The remainder of the paper is organized as follows: The model to be estimated is described in Section II. Section III describes the estimation procedure and presents results of tests for country heterogeneity and serial correlation. The model estimates are presented and discussed in Section IV. The final section provides some brief concluding comments on the specification of the model and the estimated relationships.

II. Specification of the Model

This section develops a simple model for a small open developing country which can be estimated using a pooled sample of time series data from a large number of countries. In specifying the behavioral relationships as well as the structure of the economy, we have chosen to work with conventional, widely-used specifications to the greatest extent possible, subject to the data limitations inherent in developing-country applications. The model is of the Mundell-Flemming variety, with one domestically-produced good consumed both at home and abroad and one imported good. The specification allows for the existence of capital controls, while permitting the degree of effective capital mobility to be tested empirically. The discussion is divided up into descriptions of aggregate demand, aggregate supply, the money market, and the government sector. The last sub-section examines the overall structure of the model.

1. Aggregate demand

Real aggregate demand for domestic output is the sum of consumption, investment, government expenditure, and the trade balance:

$$Y_t = C_t + I_t + G_t + X_t - \frac{e_t P^*_t Z_t}{P_t} \tag{1}$$

The variables in equation (1) are defined as follows: Y_t is real GDP; C_t is real private consumption expenditure; I_t is real gross domestic investment expenditure; G_t is real government expenditure on the domestic good; X_t denotes real exports; e_t is the nominal exchange rate (price of foreign currency in domestic-currency terms); Z_t is real imports measured in units of the foreign good; P^*_t is the foreign-currency price of imports; and P_t is the domestic-currency price of domestic output.

Turning to the components of demand, the consumption function is specified as follows:

$$\log C_t = \alpha_o + \alpha_1 r_t + \alpha_2 \log C_{t-1} + \alpha_3 \log Y^d_t + \alpha_4 \log Y^d_{t-1} \tag{2}$$

where r_t is the domestic real rate of interest, Y_t^d is real disposable income, and the α_i's are coefficients to be estimated. 1/ The short-run interest semi-elasticity of consumption is measured by the parameter α_1. 2/ In this general specification are nested a number of alternative hypotheses about consumption. For example, if $\alpha_o = \alpha_1 = \alpha_3 = \alpha_4 = 0$ and $\alpha_1 = 1$, the simplest Hall (1978) version of the permanent income hypothesis with no liquidity constraints is obtained. 3/ If only the disposable income terms are rejected empirically, the specification would be consistent with more general-Euler equation approaches which predict that, in the absence of new information, consumption grows from period to period at a rate that depends on the rate of interest. 4/ As a number of studies have shown, current disposable income would be important in an equation of this type (i.e., $\alpha_3 > 0$) if liquidity constraints are binding for a significant portion of households. 5/ Finally, the coefficient of the lagged disposable income term can also provide a test for the Blanchard hypothesis of finite horizons for private agents. 6/

Consumer disposable income, a variable used in the consumption function above, is defined to be GDP plus the earnings on net assets held abroad, minus interest paid on domestic debt and taxes:

$$Y_t^d = Y_t + i_t^* e_t \frac{F_{p,t-1}}{P_t} - i \frac{DC_{p,t-1}}{P_t} - T_t \qquad (3)$$

where i_t^* is the (nominal) foreign interest rate, $F_{p,t}$ is the stock of foreign assets held by the private sector (measured in foreign currency terms), $DC_{p,t}$ is the stock of domestic bank credit held by the private sector, and T is real taxes. Disposable income and consumer expenditure are linked to the net change in consumer wealth by the private sector budget constraint:

1/ This specification is very close to that of Blinder and Deaton (1985). See also Lahiri (1989), who estimates a similar function for several Asian economies.

2/ It might be noted that few studies have found reliable or significant estimates of interest elasticities of consumption in developing countries. See for example Rossi (1988).

3/ See Hall (1978).

4/ See Rossi (1988) and Giovaninni (1985).

5/ See Flavin (1981).

6/ See Haque (1988) and Haque and Montiel (1989).

$$Y_t^d = C_t + I_t + \left\{(M_t - M_{t-1}) + e_t(F_{p,t} - F_{p,t-1}) - (DC_{p,t} - DC_{p,t-1})\right\}/P_t$$

where M_t denotes the money supply in period t. Disposable income is thus allocated to consumption, investment, and net changes in financial assets.

Investment is specified in a fairly standard way, that is as a linear function of the real interest rate, real output, and the beginning-of-period capital stock: 1/

$$I_t = k_o + k_1 r_t + k_2 Y_t + k_3' K_{t-1} \tag{4}$$

Taking first differences this becomes:

$$I_t = k_1 (r_t - r_{t-1}) + k_2 (Y_t - Y_{t-1}) + k_3 I_{t-1} , \tag{5}$$

where $k_3 = 1 + k_3'$. This transformation eliminates the capital stock, a variable for which no developing-country data are available.

Exports are assumed to be a function of the real exchange rate ($e_t P_t^*/P_t$) and the level of real output abroad (Y^*), with positive coefficients for both variables. 2/ To incorporate partial adjustment, a lagged export term is included in the estimated equation. The export equation may therefore be expressed as follows: 3/

$$\log X_t = \tau_o + \tau_1 \log \frac{e_t P_t^*}{P_t} + \tau_2 \log Y_t^* + \tau_3 \log X_{t-1} \tag{6}$$

Real imports are related negatively to the real exchange rate and positively to real domestic output. This specification is quite

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1/ For a discussion of investment functions in developing countries, see Blejer and Khan (1984a and b), and Sundararajan and Thakur (1980).

2/ See Goldstein and Khan (1985) for a discussion of empirical estimates of such an export function. See also Khan (1974), and Khan and Knight (1988) for the case of developing countries.

3/ Note that the Mundell-Fleming structure of this model implies that exports and domestic output are perfect substitutes.

conventional. 1/ Again, to capture partial adjustment behavior a lagged import term is included in the estimated equation. Furthermore, since foreign exchange availability is frequently a constraint on imports in developing countries, the reserve-import ratio lagged one period is often included in this regression. 2/ The import equation can, therefore, be written as:

$$\log Z_t = \delta_o + \delta_1 \log \frac{e_t P^*_t}{P_t} + \delta_2 \log Y_t + \delta_3 \log \frac{R_{t-1}}{P^*_{t-1} Z_{t-1}} + \delta_4 \log Z_{t-1} \tag{7}$$

where R_t is the foreign-exchange value of international reserves.

2. Aggregate supply

We assume a Cobb-Douglas production function relating labor and capital to output:

$$Y_t = \theta_o K^{\theta_1} L^{\theta_2} \tag{8}$$

where K and L are measures of the aggregate capital stock and employment and $\theta_i (i = 0, 1, 2)$ are coefficients to be estimated. Estimation of the supply side of the model encounters the serious problem that few developing countries possess data on the aggregate capital stock. The following procedure was therefore adopted. The solution to the difference equation $K_t = (1 - \rho) K_{t-1} + I_t$, where ρ is the rate of depreciation, can be written (after taking logs) as:

$$\log K_t = \log \left[\sum_{i=o}^{t-1} (1 - \rho)^i I_{t-i} + (1 - \rho)^t K_o \right] 0 \tag{9}$$

$$\approx \log 2 + \frac{1}{2} \left[\log \sum_{i=o}^{t-1} (1 - \rho)^i I_{t-i} + \log (1 - \rho)^t K_o \right]$$

1/ Once again, empirical applications of this specification are extensively discussed in Goldstein and Khan (1985).

2/ See Khan and Knight (1988).

$$= \log 2 + \frac{1}{2} \log \sum_{i=o}^{t-1} (1 - \rho)^{i} I_{t-1} + \frac{t}{2} \log (1 - \rho) + \frac{1}{2} \log K_o$$

where K_o is the initial stock of capital. 1/

Thus,

$$\log Y_t = \log \theta_o + \theta_1 \log K_t + \theta_2 \log L_t$$

$$= \log \theta_o + \theta_1 \left[\log 2 + \frac{1}{2} \log \sum_{i=o}^{t-1} (1-\rho)^{i} I_{t-1} + \frac{t}{2} \log (1-\rho) + \frac{1}{2} \log K_o\right]$$

$$+ \theta_2 \log L_t$$

$$= \theta'_o + \theta_1 K'_t + \theta_2 \log L_t \tag{10}$$

where

$$\theta'_o = \log \theta_o + \frac{\theta_1}{2} \log K_o, K'_t = \log 2 + \frac{1}{2} \log \sum_{i=0}^{t-1} (1-\rho)^{i} I_{t-i} + \frac{t}{2} \log (1-\rho) .$$

1/ We used the approximation:

$$\log(x+y) \approx \log 2 + \frac{1}{2} (\log x + \log y) + \frac{1}{8} (\log x - \log y)^{2} + \ldots , \text{ where}$$

$$x = \sum_{i=0}^{t-1} (1-\rho)^{i} I_{t-i} \text{ and } y = (1-\rho)^{t} K_o.$$

In our estimation the first order term was found to be adequate.

Note that (10) can be estimated for different values of δ over the interval (0,1), and optimal values of θ_0', θ_1 and θ_2 will correspond to that value of ρ which maximizes the $\bar{R}^2$ in (10). By imposing constant returns to scale (i.e., $\theta_1 + \theta_2 = 1$), (10) can be written in per capita terms as:

$$\log (Y_t/L_t) = \theta_o' + \theta_1 (K_t' - \log L_t) \tag{11}$$

To allow for lagged adjustment and technical progress over time, we also included log $(Y/L)_{t-1}$ and a time trend, t, as additional explanatory variables in our final specification. Thus the empirical production function becomes:

$$\log (Y/L)_t = \theta_o' + \theta_1 (K_t' - \log L_t) + g.t + \theta_3 \log (Y/L)_{t-1} \tag{12}$$

The degree of wage-price flexibility in developing countries is an unsettled issue. The present model is estimated on the assumption of complete wage-price flexibility. Under these circumstances, equation (12) also represents the economy's aggregate supply function.

3. <u>Money market</u>

The supply of money (M) in the economy consists of reserves and domestic credit, with the latter denoted as DC:

$$M_t = e_t R_t + DC_t \tag{13}$$

While reserves are determined endogenously by the balance of payments (see below), domestic credit both to the private sector ($DC_{p,t}$) and to the public sector ($DC_{G,t}$), is determined by policy:

$$DC_t = DC_{p,t} + DC_{G,t} \tag{14}$$

The demand for money is, as usual, hypothesized to be related negatively to the nominal rate of interest and positively to the level of income, with a partial adjustment mechanism introduced to capture lagged responses:

$$\log \frac{M_t}{P_t} = \beta_o + \beta_1 i_t + \beta_2 \log Y_t + \beta_3 \log Y_{t-1} + \beta_4 \log \frac{M_{t-1}}{P_{t-1}} \qquad (15)$$

The lagged term in Y allows for different speeds of adjustment of the demand for money to changes in interest rates and income. 1/

The specification of the determination of the domestic nominal interest rate allows us to test for the effective degree of capital mobility in the economy. If capital is perfectly mobile, as is frequently assumed in small open economy models, nominal interest rates are determined by the interest parity condition that equates the domestic nominal interest rate to the sum of the nominal rate prevailing abroad and the expected change in the value of the domestic currency (uncovered interest parity). In a completely closed economy, on the other hand, nominal interest rates have no relationship to external rates and are determined purely in domestic markets. Our formulation follows Edwards and Khan (1985) in specifying the domestic interest rate as a linear combination of these two polar cases:

$$i_t = \phi \left(i_t^* + \frac{E_t e_{t+1} - e_t}{e_t}\right) + (1-\phi)\, \tilde{i}_t \qquad (16)$$

Here $E_t e_{t+1}$ is the expectation at the time t of the exchange rate in period t+1, $\tilde{i}_t$ is the interest rate that would prevail if the capital account were closed, and ϕ is a capital mobility index. $\phi = 1$ implies that the domestic interest rate is determined by the uncovered interest parity condition, and thus corresponds to perfect capital mobility, whereas $\phi = 0$ implies that the domestic interest rate is $\tilde{i}$--i.e., that which would emerge under a completely closed capital account. As ϕ increases from 0 to 1, the degree of capital mobility increases, since i approaches its uncovered parity value. In these intermediate cases the equilibrium interest rate is determined by a combination of domestic and external factors.

1/ The additional lagged term in Y permits the demand for money to adjust more slowly in response to changes in income than to changes in interest rates.

The interest rate that would prevail in an economy with a closed capital account (i.e., one with no private capital flows), $\tilde{i}_t$, can be determined by equating the money supply that would be observed in this case to the demand for money. This "shadow" money supply (denoted $\tilde{M}$) differs from the supply of money given by equation (13) in that the effects of current private capital flows on the central bank's stock of foreign exchange reserves are removed:

$$\tilde{M}_t = M_t + e_t \Delta F_{p,t} \tag{17}$$

Thus the "shadow" domestic interest rate $\tilde{i}_t$ can be obtained by solving the following equation:

$$\log \frac{\tilde{M}_t}{P_t} = \beta_o + \beta_1 \tilde{i}_t + \beta_2 \log Y_t + \beta_3 \log Y_{t-1} + \beta_4 \log \frac{M_{t-1}}{P_{t-1}}, \tag{18}$$

In this model the authorities use capital controls to pursue an independent monetary policy, as follows: for a desired level of the domestic interest rate, say $\bar{i}_t$, the level of the domestic money supply required to clear the money market, say $\bar{M}_t$, is given by setting $i = \bar{i}$ in the money-market equilibrium condition (15).

Given $\bar{M}_t$ from equation (15) and the supply of credit DC_t, equation (13) determines foreign exchange reserves R_t. Subtracting the previous period's reserves R_{t-1} yields the balance of payments (ΔR_t). Using the balance of payments identity:

$$e_t \Delta R_t = CA_t - e_t (\Delta F_{G,t} + \Delta F_{p,t}) \tag{19}$$

where:

$$CA_t = P_t X_t - e_t P^*_t Z_t + i^*_t e_t (F_{P,t-1} + F_{G,t-1} + R_{t-1}) \tag{20}$$

the authorities can derive the permissible level of private capital flows, $\overline{\Delta F}_{p,t}$, conditional on the current account CA_t and public capital outflows $\Delta F_{G,t}$.

The authorities could choose to administer this system in a number of ways. If either i_t or $\Delta F_{p,t}$ is treated as an exogenous variable, the other becomes endogenous and equation (16) drops out of the model. With i_t exogenous, the authorities announce a domestic interest rate, solve for the value of $\Delta F_{p,t}$ required to support it, and permit this degree of capital mobility. Equation (16) becomes unnecessary, useful only for calculating a period-by-period index ϕ_t of the degree of capital mobility. Alternatively, the authorities could choose $\Delta F_{p,t}$ exogenously, with (19) determining R_t, (13) determining M_t, and (15) the domestic interest rate. The role of (16) would then be as in the previous case.

We will assume instead that the system is run somewhat less flexibly. The severity of capital controls, as measured by the parameter ϕ in equation (16), is taken as a structural (institutional) feature of the economy. In this case, both i_t and $\Delta F_{p,t}$ become endogenous. The domestic interest rate i_t will respond to factors affecting both the uncovered parity and the shadow interest rates. For the money market to clear, $\Delta F_{p,t}$ must be adjusted in response to these factors as well. Notice that the structural interpretation of ϕ permits its magnitude to be estimated empirically, in a manner to be discussed in the next section.

The real interest rate enters the model in both the consumption and investment functions. It is given by:

$$r_t = i_t - \frac{E_t P_{t+1} - P_t}{P_t} , \tag{21}$$

i.e., the real interest rate is the nominal rate minus the expected rate of inflation.

4. Government

The model's dynamic specification is completed with a description of the behavior of the nonfinancial public sector. The public sector borrows in external markets ($F_{G,t}$) as well as from the domestic banking sector ($D_{G,t}$). For its revenues it relies on tax receipts, T_t, and interest on its foreign asset holdings. Expenditures (G_t) consist of purchases of domestic goods for consumption purposes and interest payments on domestic debt. Combining these elements, the government budget constraint can be written as:

$$e_t \, \Delta F_{G,t} - \Delta DC_{G,t} = P_t \, (T_t - G_t) + i_t^* \, e_t \, F_{G,t-1} - i_t \, DC_{G,t-1} \tag{22}$$

5. Overall structure of the model

The model that emerges from this specification is essentially a flexible-price dynamic variant of the traditional Mundell-Fleming model with specific developing-country features. A single good is produced domestically, which can be sold at home or abroad. The home country has some monopoly power over the price of its output in world markets. It is a price-taker, however, in the market for its imports. On the other hand, as is common in developing countries, private agents may not be able to satisfy their notional demand for imports, because the authorities impose quantitative import restrictions which depend on the adequacy of their foreign exchange reserves. On the financial side, the degree of integration of the home economy with the rest of the model depends on the severity with which capital controls are enforced. In principle, this can range from financial autarky to perfect capital mobility. The dynamics of the model arise from forward-looking expectations, partial adjustment in the behavioral relationships, and stock accumulation. Since the level of investment and the current account are endogenous, the model can explain medium-term growth and external debt accumulation. Since expectations are forward looking, these phenomena will depend not just on present, but also on future, values of the policy and exogenous variables.

III. Estimation Issues

The equations to be estimated are (2), (5), (6), (7), (12), (15), and (16). The approach to estimation used here assumes that the slope parameters do not change across countries. The estimates should therefore be interpreted as "typical" of developing countries in general rather than as specific to any particular country. This approach allows us to exploit the variation in data both across countries and within countries over time to estimate key macroeconomic parameters. We used annual data over 1963-1987 for 31 developing countries 1/ collected from the World Economic Outlook database and International Financial Statistics. In this section we discuss three estimation issues: the problem of unobserved variables, the approach to estimation with rational expectations, and the treatment of country heterogeneity. The estimated equations themselves are presented in Section IV.

1. Unobserved variables

The first estimation issue to be confronted is the absence of data on the relevant market-determined interest rate i_t and, of course, the shadow interest rate $\tilde{i}_t$. This problem can be addressed by solving equation (18) for $\tilde{i}_t$, and then substituting the resulting expression for $\tilde{i}_t$ into (16) to

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1/ The countries in the sample are: Brazil, Chile, Colombia, Costa Rica, Ecuador, Egypt, Ethiopia, Greece, Guatemala, India, Indonesia, Jamaica, Jordan, Kenya, Korea, Malawi, Malaysia, Malta, Mexico, Morocco, Nigeria, Paraguay, Philippines, South Africa, Sri Lanka, Tanzania, Thailand, Tunisia, Turkey, Venezuela, and Zambia.

solve for i_t. The expression for i_t can be substituted into (21) to obtain the real interest rate r_t. The solution for the nominal interest rate can be used to eliminate i_t from the money-demand function (15), while the solution for the real interest rate can be used to eliminate r_t from both the consumption function (2) and the investment function (5). The revised equations (2), (5), and (15) are nonlinear in the structural parameters and subject to cross-equation restrictions among these parameters. This procedure has the virtue of not only making it possible to estimate the parameter ϕ, but also of permitting us to extract estimates of interest-rate elasticities in consumption, investment, and money demand, which do not depend on proxies for market interest rates such as administered interest rates or inflation rates. The resulting system to be estimated consists of the revised versions of equations (2), (5), and (15)--with associated nonlinear parameter and cross-equation restrictions--as well as equations (6), (7), and (12). The equations to be estimated are presented in Table 1.

2. Expectations

The next issue concerns the treatment of expectations in the estimation procedure. The assumption of rationality in our model implies that forward expectations are based on all available information, including the structure of the model. This implies the property:

$$P_{i,t+1} = E_t P_{i,t+1} + \epsilon_{i,t+1} \tag{23}$$

where $\epsilon_{i,t+1}$ is a serially uncorrelated random disturbance term. Consequently, for estimation one needs a reasonable proxy for $E_t\ P_{i,t+1}$, which now appears in the revised versions of equations (2) and (5). One such observable proxy for the unobservable price expectation variable $E_t P_{i,t+1}$ is the actual $P_{i,t+1}$. The associated estimation procedure is the errors-in-variables (EVM) method, in which the expected forward price is replaced by the realized (observed) value, and the latter is treated as an additional endogenous variable of the model. 1/ An alternative approach that has been used for estimation of simultaneous equation models with rational expectations is the so-called substitution method (SM) where the rationally-expected variables are replaced by forecasts based on a restricted reduced form. 2/ Wickens (1982, 1986) emphasizes many advantages of the EVM approach over the SM method. He shows that in a non-linear model such as ours, the additional non-linearity in the parameters introduced due to the SM will make the estimation technique hopelessly complicated. Wickens (1982, 1986) also demonstrates that the EVM is in general more robust than SM in cases where the variables in the

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1/ See McCallum (1976), Lahiri (1981), and Wickens (1982). See also Blundell-Wignall and Masson (1985).

2/ See Hansen and Sargent (1980, 1981) and Wallis (1980).

Table 1. Behavioral Equations of the Model

$$\log C_t = \alpha_o + \alpha_1 r_t + \alpha_2 \log C_{t-1} + \alpha_3 \log Y^d_t + \alpha_4 \log Y^d_{t-1} \qquad (2)$$

$$I_t = k_1 (r_t - r_{t-1}) + k_2 (Y_t - Y_{t-1}) + k_3 I_{t-1} , \qquad (5)$$

$$\log X_t = \tau_o + \tau_1 \log \frac{e_t P^*_t}{P_t} + \tau_2 \log Y^*_t + \tau_3 \log X_{t-1} \qquad (6)$$

$$\log (Y/L)_t = \theta'_o + \theta_1 (K'_t - \log L_t) + g.t + \theta_3 \log (Y/L)_{t-1} \qquad (12)$$

$$\log \frac{M_t}{P_t} = \beta_o + \beta_1 i_t + \beta_2 \log Y_t + \beta_3 \log Y_{t-1} + \beta_4 \log \frac{M_{t-1}}{P_{t-1}} \qquad (15)$$

$$i_t = \phi (i^*_t + \frac{E_t e_{t+1} - e_t}{e_t}) + (1-\phi) \tilde{i}_t \qquad (16)$$

information set (Ω_t) are incomplete. Moreover, EVM is relatively easy to implement, making it more amenable to repeated experimentation with different specifications of the model. In addition, Wickens (1986) shows that until the type of rational expectations solution exhibited by the model is known, it will not be possible to select the appropriate fully efficient SM estimator.

The reduced-form equation for P_t in country i can be obtained by linearizing the model, solving it for P_t, leading it one period, taking expectations conditional on Ω_t, and solving for E_tP_{it+1}. If we write

$$E_tP_{it+1} = \Pi \cdot X_{it} \tag{24}$$

where X_{it} is the set of instruments belonging to Ω_t and Π is a vector of reduced-form coefficients, then (23) becomes:

$$P_{it+1} = \Pi \cdot X_{ir} + \eta_{i,t+1} \tag{23'}$$

This equation can be used to generate the instruments for P_{it+1}. In estimating the behavioral equations of the revised model, therefore, E_tP_{it+1} was replaced by P_{it+1} and C_{it}, I_{it}, X_{it}, Z_{it}, M_{it}, Y_{it}, P_{it} and P_{it+1} were treated as endogenous variables (i.e., not part of the set of instruments). This yields consistent estimates of the structural parameters. Note that in order to identify and estimate all the structural parameters we have to estimate the system of equations together, incorporating the non-linear restrictions both within and across equations.

3. Tests of heterogeneity and serial correlation

In using pooled cross-section, time-series data the issue of country heterogeneity has to be confronted. Most studies that use such data for empirical estimation rely on dummy variables to deal with country heterogeneity, primarily for ease of estimation. 1/ In this study, we adopted the alternative approach of variance components. Under this assumption, the error term of the jth equation, η_j, is composed of two terms: η_{ji}, the country-specific effect, which varies only across countries and not across time, and ε_{jit}, an individual random effect which may differ for all observations. Consequently, the error term is written as:

$$u_{jit} = \eta_{ji} + \varepsilon_{jit} \tag{25}$$

1/ See, for example, Khan and Knight (1981).

for t = 1, 2, ..., T; i = 1, 2, ..., N and j = 1, 2, ..., M. Moreover,

$$E(\eta_{ji}) = E(\varepsilon_{jit}) = 0 \qquad (26)$$

$$E(\eta_{ji}\,\eta_{j'i'}) = \begin{cases} \sigma_{\eta jj} & \text{for } i = i' \text{ and } j = j'; \\ \sigma_{\eta jj'} & \text{for } i = i' \text{ and } j \neq j'; \\ 0 & \text{otherwise} \end{cases}$$

$$E(\varepsilon_{jit}\,\varepsilon_{j'i't'}) = \begin{cases} \sigma_{\varepsilon jj} & \text{for } i = i', j = j', \text{ and } t = t' \\ \sigma_{\varepsilon jj'} & \text{for } i = i', j \neq j', t = t'; \\ 0 & \text{otherwise} \end{cases}$$

$$E(u_{ji}\,\varepsilon_{j'i't}) = 0$$

for t, t' = 1, 2, ... T; i, i' = 1, 2, ... N; j, j' = 1, 2, ... M.

Together these assumptions imply that the variance structure of the composite disturbance term μ is given by:

$$E(u_{jit}\,u_{j'i't'}) = \begin{cases} \sigma_{\eta jj} + \sigma_{\varepsilon jj} & \text{for } j = j', i = i', \text{ and } t = t' \\ \sigma_{\eta jj} & \text{for } j = j', i = i', \text{ and } t \neq t' \\ \sigma_{\eta jj'} + \sigma_{\epsilon jj} & \text{for } j \neq j', i = i', \text{ and } t = t' \\ \sigma_{\eta jj'} & \text{for } j \neq j', i + i', \text{ and } t \neq t' \\ 0 & \text{otherwise} \end{cases} \qquad (27)$$

The variance-covariance matrix of the disturbance term for the jth equation can therefore be written as follows:

$$E(U_j U_j') = \Sigma_{jj} = \sigma_{\eta jj} A + \sigma_{\epsilon jj} I_{NT} \tag{28}$$

where $A = I_N \otimes \ell_T \ell_T'$ with $\otimes$ defining the Kronecker product and ℓ_T being a T-vector of ones. Denoting the M x M variance-covariance matrix for η and ε for the system of equations by Σ_η and Σ_ε respectively, the MNT x MNT variance covariance matrix for the system-wide vector of disturbances $u = (u_1' \ldots u_m')'$ may be written as:

$$E(u\, u') = \Sigma = \Sigma_\eta \otimes A + \Sigma_\varepsilon \otimes I_{NT} \tag{29}$$

As is well known, variance-components characterization of country heterogeneity has the advantage that GLS estimation techniques can be used to consistently estimate the model parameters as well as the variance components of the random error term. In order to deal with the error-component structure of the variance of the random error term in the model, generalized estimation techniques were implemented using a two-step procedure. 1/ At the first stage, the vector of residuals was calculated from 2SLS estimates of the model. These residual estimates, denoted $\hat{u}_{jit}$, were used to calculate the variance components as follows: 2/

$$\hat{\sigma}_{\epsilon jj} = \frac{1}{N(T-1)} \sum_{i=1}^{N} \sum_{t=1}^{T} \left[\hat{u}_{jit} - \frac{1}{T} \sum_{t=1}^{T} \hat{u}_{jit} \right]^2$$

$$\hat{\sigma}_{\eta jj} = \sum_{i=1}^{N} \frac{\sum_{t=1}^{T} \hat{u}_{jit}^2}{T(N-1)} - \hat{\sigma}_{\epsilon jj}$$

1/ For more detailed discussion of estimation with variance components see Belestra and Nerlove (1966), Hausman and Taylor (1981), Amemiya and McCurdy (1986), Breusch, Mizon and Schmidt (1989), and Maddala (1987).
2/ See Wallace and Husain (1989) and Maddala (1988).

With the variance components estimated, the variance-covariance matrix of the disturbance term can be constructed to allow generalized two-stage or three-stage least squares to be used for consistent estimation of the model parameters. Anderson and Hsiao (1983) and Sevestre and Tragnon (1986) have shown that this estimator is consistent and, for dynamic models, independent of initial conditions. In our case, a generalized non-linear three-stage least squares estimator was used due to the presence of non-linearities and cross-equation restrictions. Following Breusch, Mizon and Schmidt (1989), the instruments used were the within-country variables ($X_{jit} - \bar{X}_{ji}$) and the between-country variables (X_{ji}). They have shown that the use of this procedure allows efficient estimation in models with rational expectations and panel data.

Before proceeding to the model estimation, we tested the error components structure assumed above against the alternative of no country-specific effects. In order to perform this test, unrestricted two-stage least squares (2SLS) estimates of the behavioral equations were initially obtained based on pooled data, as well as within-country and between-country data. 1/ 2/ All predetermined variables of the model (except for the lagged endogenous variable for the equation being estimated) were used as instruments. 2SLS estimates based on pooled data were obtained in order to test for the presence of country-specific error terms in each equation. We used the Lagrange multiplier (LM) test due to Breusch and Pagan (1980) to test for the significance of $\sigma_{\eta jj}$ (j=1,...,6) in each equation. The LM statistic is given by:

$$LM = \frac{NT}{2(T-1)} \left[\frac{\sum_{i=1}^{N} \left(\sum_{t=1}^{T} \hat{U}_{it} \right)^2}{\sum_{i=1}^{N} \sum_{t=1}^{T} \hat{U}_{it}} - 1 \right]^2 \sim \chi^2_{(1)} \qquad (30)$$

1/ Note that a within-country transformation of a variable Y_{it} (i = 1, 2, .., N; t = 1, 2, .., T) is simply

$$Y_{it} - \bar{Y}_i \text{ where } \bar{Y}_i = (1/T) \sum_{i=1}^{T} Y_{it}.$$

The term "between-country data" refers to the country-specific means $\bar{Y}_i$.

2/ All equations are estimated in per capita terms in order to avoid heteroskedasticity in errors due to the widely varying sizes of the countries in our same.

where $\hat{U}_{it}$ is the 2SLS residual from each of the estimated equations. Estimates of the LM statistic are presented in Table 2. The LM statistic is distributed χ^2 (1). The estimates suggest that the null hypothesis, $\sigma_{\eta jj} = 0$, can be rejected for each of the equations. Based on estimated residuals, values of $\lambda_j = 1 - [\sigma_{\epsilon jj}/(\sigma_{\epsilon jj} + T\sigma_{\eta jj})]^{1/2}$ were calculated for each equation. 1/ Except for the money demand equation, these estimates of λ_j were fairly large. In the case of the money demand equation $\sigma_{\eta jj}$ was only 0.0003, whereas $\sigma_{\epsilon jj}$ was calculated to be 0.0085. Thus, of all the behavioral equations the money demand equation was found to be most homogenous across countries, but in each of the equations our assumption of a country-specific error term is supported by the data.

The residuals from estimated equations based solely on within-country variation in data (i.e., least squares with country dummies--LSDV) were used to test for serial correlation using a test proposed by Bhargava, Franzini and Narendranathan (1982). The statistic is given by:

$$d_p^j = \frac{\sum_{i=1}^{N} \sum_{t=2}^{T} \left(\hat{U}_{jit} - \hat{U}_{jit-1} \right)^2}{\sum_{i=1}^{N} \sum_{t=1}^{T} \hat{U}_{jit}^2} \qquad (j = 1, 2, .., M) \qquad (31)$$

where $\hat{U}_{jit}$ is the estimated residual for the jth equation. Estimates of the d_p statistic for each equation are also presented in Table 2. Using the critical values of d_p obtained by Bhargava et.al and some extrapolations of their results, serial correlation in the residuals was rejected for the consumption, investment, export, and money demand functions at the 5 percent level, and for the import and production functions at a slightly higher level of significance.

We conclude from this subsection that an error components model with no serial correlation provides a satisfactory representation of the statistical properties of the random terms in the model to be estimated.

1/ λ_j is the variable that is used to transform the data [i.e., $X^T_{ijt} = (X^i{}_{jt} - \lambda \bar{X}_{jt})$] for GLS estimation. If $\lambda_j = 0$, GLS estimation would not be required. See Balestra and Nerlove (1966).

Table 2. Estimated Test Statistics for the Lagrange-Multiplier (LM) Test, Values of λ, and d_p Statistic

Equation	LM 1/	λ	d_p
Consumption	62.4	0.49	1.95
Investment	70.2	0.52	1.90
Exports	85.2	0.94	2.04
Imports	102.3	0.91	1.75
Money demand	12.9	0.26	1.94
Production function	120.8	1.0	1.76

1/ Critical value for $\chi^2(1)$ at the 1% significance level = 6.63

IV. Model Estimates

The error-components two-stage least squares (EC2SLS) estimates and the tests showing the presence of heterogeneity and serial independence form the basis for the implementation of the error-components three-stage least squares (EC3SLS) estimation. The results of the EC3SLS estimation are presented in Table 3. As will be discussed below, these results indicate that the model fits the data well. Almost all the estimates are of the right sign and a large number of them are estimated very precisely. In what follows we shall discuss the estimates of, and the hypotheses embedded in, each of the behavioral equations separately. 1/

1. Consumption

The estimated coefficients of the consumption function are all of the anticipated signs. In magnitude these coefficients also conform well to theory as well as to consumption function estimates that are available in the literature. Interestingly enough, α_1 is negative and significant at the 10 percent level, verifying a negative relationship between consumption and the interest rate. Most studies of the consumption function have found this relationship to be statistically insignificant. Our results suggest that the use of inappropriate proxies for domestic real interest rates (e.g., the rate of inflation) may have contributed to this result. 2/ The estimated coefficient is, however, quite small, suggesting that changes in interest rates would not induce substantial changes in consumption. This result confirms Rossi's (1988) finding of a significant but small real interest rate elasticity in the consumption function.

The estimation, as it turns out, supports a number of important hypotheses relating to the consumption function that were discussed above. The specification is very similar to the Haque and Montiel (1989) version of the permanent income model. The coefficient of lagged consumption is close to one and significant as expected in the Hall (1978) specification of the permanent income hypothesis. However, contrary to the Hall hypothesis, disposable income is significant in explaining consumption

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1/ Note that our model formulation allows all the endogenous variables to be correlated with η_{ji} and ε_{jit} in all equations. However, the exogenous variables are assumed to be uncorrelated with η_{ji} and ε_{jit}. Some of the exogenous variables, however, can be correlated with η_{ji}, but uncorrelated with ε_{jit}. Cornwell, Schmidt and Wyhowski (1988) refer to this latter group as "singly" exogenous variables. For consistent estimation, the country means of the "singly" exogenous variables (i.e., $\bar{X}_i$) should not belong to the list of instrumental variables. In the context of EC2SLS estimation of each structural equation, we found that this had negligible effects on the reported estimates. Thus, our list of exogenous variables can safely be treated as "doubly" exogenous.

2/ See Giovannini (1985) for a discussion of this issue.

Table 3. Non-Linear EC3SLS Estimates of Structural Parameters

Parameters	t-ratios	Parameters	t-ratios
Consumption		Money demand	
α_o = 0.047	5.62*	β_o = -0.146	-4.36*
α_1 = -0.076	-4.08*	β_1 = -0.038	-1.27
α_2 = 1.010	96.28*	β_2 = 0.571	3.99*
α_3 = 0.143	3.64*	β_3 = -0.397	-2.79*
α_4 = -0.149	-4.23*	β_4 = 0.881	59.56*
	$\bar{R}^2$ = 0.997		$\bar{R}^2$ = 0.997
Investment		Production function	
k_o = -0.226	-6.81*	θ_1 = 0.122	6.55*
k_1 = -0.113	-4.03*	θ_3 = 0.881	63.38*
k_2 = 0.196	9.74*	g = 0.141	6.49*
k_3 = 0.809	44.94*		$\bar{R}^2$ = 0.979
	$\bar{R}^2$ = 0.980		
Exports		Imports	
τ_1 = 0.050	2.05*	δ_1 = -0.157	-5.09*
τ_2 = 0.084	1.78*	δ_2 = 0.161	6.02*
τ_3 = 0.925	82.24*	δ_3 = 0.038	5.96*
	$\bar{R}^2$ = 0.983	δ_4 = 0.834	43.21*
			$\bar{R}^2$ = 0.977
Capital mobility parameter			
ϕ = 1.004	90.59**		

* Parameter significant at the 5 percent level of significance.
** Not significantly different from one.

behavior. The coefficient of disposable income, α_3, which is statistically significant, suggests that about 15 percent of consumers in developing countries are liquidity constrained, which is on the low end of the range of estimates reported in Haque and Montiel (1989).

2. Investment

The specification of the investment function was a relatively simple one. Nevertheless, it seems to provide a reasonably good explanation of investment behavior in developing countries. Most studies of investment behavior in such countries, because of lack of adequate information, do not include interest rates as an explanatory variable. 1/ Our approach to modelling capital mobility allows the identification of the effect of the real interest rate on investment. Although small, the coefficient of the real interest rate (k_1) is negative as expected, and significant at the 5 percent level. Growth in income also affects investment positively and significantly, in keeping with the flexible-accelerator family of investment theories. The coefficient of lagged investment, k_3, is close to but less than one, indicating both a stable investment function as well as a fairly protracted period of adjustment. Using this estimate, the long-run interest rate and output elasticities can be calculated--they turn out to be 0.59 and 1.02 respectively. Thus, as can be expected, in the long run, when all adjustments have been completed, the interest elasticity is substantially larger than it is on impact. Moreover, the steady-state property that per-capita output and investment grow at the same rate is satisfied.

3. Aggregate supply

All the variables in the estimated aggregate supply (production) function are significant and of the right sign. 2/ Since θ_0 contains log K_0, which is an initial value parameter representing the initial stock of capital for each country, (12) was estimated from the "within" dimension of the data. The parameter ρ was estimated to be 0.05, though estimates of (θ_1, g, θ_3) were not particularly sensitive to values of ρ in the vicinity of 0.05. 3/ The per capita stock of capital affects current output significantly and positively with a short-run elasticity of 0.12 and of close to unity in the long run. At the sample means our results, which are derived from a log-linear specification, compare quite favorably to the estimates of Dadkhah and Zahedi (1986).

1/ See Blejer and Khan (1984a and b).

2/ Since aggregate employment data are seldom available for developing countries, we used the population as a proxy for L.

3/ It is interesting to note that this 5 percent value is consistent with those in Sundarajan and Thakur (1980) and Blejer and Khan (1984b).

4. Foreign trade

The estimated export function also fits the data well, with all coefficients bearing the expected signs. The fitted equation exhibits a significant export response to relative price changes, though one which is somewhat smaller in magnitude than other available estimates. 1/ The long run elasticity of 0.66, though considerably higher than the short run elasticity, still suggests a fairly inelastic response. In the estimated (foreign) demand for exports function, the coefficient of foreign income is positive and significant, with a long run elasticity of 1.12. A fair amount of persistence in the level of exports appears to be indicated by the coefficient of lagged exports, which is both significant and close to unity, so that the response to changes in relative prices and foreign income tends to be quite prolonged over time.

In the import equation also, the estimated coefficients bear the right signs and are all significant at conventional levels. Imports are responsive to real exchange rate changes with a short run elasticity of -0.157 and a long run elasticity of about -0.94. Growth in the domestic economy increases imports, with an elasticity of 0.16 in the short run and about 0.96 (not significantly different from unity) in the long run. Reflecting foreign exchange constraints, the coefficient of the lagged reserve-import ratio is significant and positive. These estimates are similar to those in Khan and Knight (1988).

Our results suggest that the trade equations are not as responsive to real-exchange rate changes and income growth as other studies have previously estimated. However, in comparing these results it must be borne in mind that most available estimates of such equations were constructed in a partial equilibrium setting. The estimates presented here, by contrast, are in the context of a complete macroeconomic model.

5. Money and capital mobility

The coefficients of the estimated money demand function are all significant and of the expected sign. Money demand, in keeping with expectations, is quite interest-inelastic, with the short-run interest elasticity estimated to be about -0.03 and the long-run elasticity estimated at about -0.26. The estimated income elasticities are much higher: the short- and long-run elasticities turn out to be 0.22 and 1.82 respectively. 2/

1/ See Khan (1974), Goldstein and Khan (1985), and Khan and Knight (1988).

2/ Estimates of income elasticities of money demand substantially above unity are quite common in developing countries. See Khan (1980).

As described above, our modelling approach and method of estimation allows us to estimate the effective degree of capital mobility (indexed by the parameter ϕ) for this group of developing countries. Somewhat surprisingly, the estimate of ϕ turns out to be insignificantly different from one, suggesting that capital was in effect perfectly mobile for these countries over our sample period. This result supports the validity of the small open-economy approach to modelling the financial sector in developing economies and implies that economic agents readily find ways to get around barriers to capital mobility. Thus, the uncovered interest parity condition can be used to proxy for interest rates in modeling developing economies. 1/

V. Conclusions

This paper attempts to fill a void in empirical developing-country macroeconomics. There is at present no consensus on "representative" developing-country values of the parameters of key macroeconomic behavioral relationships. Though empirical estimates are available for these parameters, the lack of convergence of views reflects differences in the specifications estimated by various analysts, in data definitions and time periods and countries covered, and in empirical methodology. In this paper, using conventional, widely-accepted specifications and appropriate econometric techniques, we pooled consistent time series data for 31 developing countries to derive estimates for the key behavioral parameters of a small but complete model of a small open developing economy. The model itself is innovative only in that expectations are formed rationally, and in that the severity of capital controls is treated as a structural feature of the economy that is subject to empirical estimation.

The estimates and test statistics presented above suggest that the model is not far off the mark as a framework for developing-country macroeconomic analysis. Its estimated parameters conform to standard economic theory, and in many cases approximate those that are available in the literature.

The most surprising result that emerged from the estimation was the verification of perfect effective capital mobility for this group of countries. Barriers to capital mobility would seem to be totally ineffectual. This result has important policy implications--i.e., it suggests that little leverage can be exercised on domestic aggregate

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1/ In view of this result we re-estimated the model, imposing perfect capital mobility to see if the coefficients were altered in any significant manner. The results are essentially unchanged, with the exception of the consumption function. This function exhibited substantially greater interest-rate elasticity. The estimated fraction of liquidity-constrained households was about a third, a result which is much closer to the estimates in Haque and Montiel (1989).

demand through monetary policy in these countries, though the effects of changes in credit policy on the balance of payments may be substantial. On the other hand, although we were able to estimate substitution elasticities rather precisely, our estimated values were in many cases somewhat lower than available estimates. This interaction of low substitution elasticities, perfect capital mobility, and forward-looking behavior represents a possible framework within which to study the dynamic response of developing economies to both exogenous and policy shocks.

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