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A Macroeconometric Model for Developing Countries

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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 macroeconomic analysis of developing countries. The specification of the model allows the hypothesis of capital mobility to be explicitly tested, and the empirical analysis suggests that, on average, developing countries have exhibited a high degree of capital mobility. [JEL 131, 431]

DESPITE THE increased attention that macroeconomic management in developing countries has received during the past 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

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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 is even more pronounced at the empirical level. Substantial disagreement exists over the general specification of such models, as well as over the orders of magnitude of certain key macroeconomic parameters—for example, 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, all of which have important implications for economic policy. Although estimates of macroeconomic parameters such as these are indeed available for developing countries, they differ greatly with regard to countries and periods covered, specifications of estimated equations, and—possibly most important—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, using a uniform data set for a relatively large group of countries and relying on appropriate empirical techniques to obtain these estimates. Because our interest is in providing reasonable empirical estimates of widely used parameters, we construct a fairly simple macroeconomic model using widely accepted developing country specifications for the key behavioral relationships wherever possible. The structural parameters are then estimated as a system.

Although, for the reason just explained, the behavioral relationships in our model are conventional, our work differs from existing developing country empirical macroeconomic models in two important ways. First, we assume that expectations are formed rationally by forward-looking economic agents. Second, we make explicit allowance for the presence of capital controls, the latter being a feature which, though pervasive in developing economies and often mentioned in policy discussions, 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 I. Section II describes the estimation procedure and presents the estimation results. The model estimates are discussed in Section III. The final section provides some brief comments on the specification of the model and the estimated relationships.

I. 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.[1] 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 subsection examines the overall structure of the model.

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 gross domestic product (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:

$$\log C_t = \alpha_0 + \alpha_1 r_t + \alpha_2 \log C_{t-1} + \alpha_3 \log Y_t^d + \alpha_4 \log Y_{t-1}^d, \tag{2}$$

[1] Although a three-good (exportable-im ortable-nontraded) structure might be more appropriate for developing countries, data limitations make it infeasible to implement the estimation of a model with this structure across a large group of developing countries.

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.[2] The short-run interest semi-elasticity of consumption is measured by the parameter α_1.[3] In this general specification are nested a number of alternative hypotheses about consumption. For example, if $\alpha_0 = \alpha_1 = \alpha_3 = \alpha_4 = 0$, and $\alpha_2 = 1$, the simplest Hall (1978) version of the permanent-income hypothesis with no liquidity constraints, in which current consumption is systematically related only to its own past value, is obtained (see Hall (1978)). 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 (see Rossi (1988) and Giovannini (1985)). As a number of studies have shown, current disposable income would be important (that is, $\alpha_3 > 0$) in an equation of this type estimated with instrumental variables if liquidity constraints are binding for a significant portion of households, since in this case aggregate consumption would include a portion that is attributable to liquidity-constrained households whose consumption is constrained by current income (see Flavin (1981)). Finally, the coefficient of the lagged disposable income term can also provide a test for the Blanchard hypothesis of finite horizons for private agents. As shown in Haque (1988), if the planning horizons of households that do not face liquidity constraints are effectively of infinite length, $\alpha_4 = 0$; otherwise, α_4 will be negative (see also Haque and Montiel (1989)).

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:

$$Y_t^d = Y_t + \frac{i_t^* e_t F_{p,t-1}}{P_t} - \frac{iDC_{p,t-1}}{P_t} - T_t, \tag{3}$$

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:

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

where M_t denotes the money supply in period t. Disposable income is

[2]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.

[3]Few studies have found reliable or significant estimates of interest elasticities of consumption in developing countries. See, for example, Rossi (1988).

thus allocated to consumption, investment, and net changes in financial assets.

Investment is specified as a function of fairly standard variables—that is, the real interest rate, real output, and the beginning-of-period capital stock.[4] We adopt a linear formulation, since this permits us to avoid the problem of the absence of capital stock data by first-differencing the equation. The investment function is

$$I_t = k_0 + k_1 r_t + k_2 Y_t + k_3' K_{t-1}. \tag{4}$$

With 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.[5] To incorporate partial adjustment, a lagged dependent variable is included in the estimated equation. The export equation may therefore be expressed as follows:[6]

$$\log X_t = \tau_0 + \tau_1 \log \frac{e_t P_t^*}{P_t} + \tau_2 \log Y_t^* + \tau_3 \log X_{t-1}. \tag{6}$$

Real imports are related negatively to the real exchange rate and positively to real domestic output. This specification is conventional.[7] Again, to capture partial adjustment behavior a lagged import term is included in the estimated equation. Furthermore, since restricted foreign exchange availability frequently leads to the imposition of import controls and foreign exchange rationing, which act as a constraint on imports in developing countries, the reserve-import ratio lagged one period is often included in this regression (see Khan and Knight (1988)). The import equation can therefore be written as

$$\log Z_t = \delta_0 + \delta_1 \log \frac{e_t P_t^*}{P_t} + \delta_2 \log Y_t + \delta_3 \log \frac{R_{t-1}}{P_{t-1}^* Z_{t-1}} + \delta_4 \log Z_{t-1}, \tag{7}$$

where R_t is the foreign exchange value of international reserves.

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

[5] 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 count ies.

[6] Note that the Mundell-Fleming structure of this model implies that exports and domestic output are perfect substitutes.

[7] Once again, empirical applications of this specification are extensively discussed in Goldstein and Khan (1985).

Aggregate Supply

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

$$Y_t = \theta_0 K^{\theta_1} L^{\theta_2}, \tag{8}$$

where K and L are measures of the aggregate capital stock and employment and the θ_i's ($i = 0, 1, 2$) are coefficients to be estimated. As with the investment function, estimation of the supply side of the model is hampered by the shortage of data on aggregate capital stock for developing countries. 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

$$\begin{aligned}
\log K_t &= \log\left[\sum_{i=0}^{t-1} (1-\rho)^i I_{t-i} + (1-\rho)^t K_0\right] \\
&\approx \log 2 + \frac{1}{2}\left[\log \sum_{i=0}^{t-1} (1-\rho)^i I_{t-i} + \log\,(1-\rho)^t K_0\right] \\
&= \log 2 + \frac{1}{2}\log \sum_{i=0}^{t-1} (1-\rho)^i I_{t-i} + \frac{t}{2}\log(1-\rho) + \frac{1}{2}\log K_0,
\end{aligned} \tag{9}$$

where K_0 is the initial stock of capital.[8]

Thus,

$$\begin{aligned}
\log Y_t &= \log \theta_0 + \theta_1 \log K_t + \theta_2 \log L_t \\
&= \log \theta_0 + \theta_1\left[\log 2 + \frac{1}{2}\log \sum_{i=0}^{t-1} (1-\rho)^i I_{t-i}\right. \\
&\qquad \left. + \frac{t}{2}\log\,(1-\rho) + \frac{1}{2}\log K_0\right] + \theta_2 \log L_t \\
&= \theta_0' + \theta_1\, K_t' + \theta_2 \log L_t,
\end{aligned} \tag{10}$$

[8] We used the approximation

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

where

$$x = \sum_{i=0}^{t-1} (1-\rho)^i I_{t-i} \quad \text{and} \quad y = (1-\rho)^t K_0.$$

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

where

$$\theta_0' = \log \theta_0 + \frac{\theta_1}{2} \log K_0$$

$$K_t' = \log 2 + \frac{1}{2} \log \sum_{i=0}^{t-1} (1-\rho)^i I_{t-i} + \frac{t}{2} \log (1-\rho).$$

Note that equation (10) can be estimated for different values of ρ 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 $\overline{R}^2$ in equation (10). By imposing constant returns to scale (that is, $\theta_1 + \theta_2 = 1$), equation (10) can be written in per capita terms as

$$\log (Y_t/L_t) = \theta_0' + \theta_1 (K_t' - \log L_t). \tag{11}$$

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

$$\log (Y/L)_t = \theta_0' + \theta_1 (K_t' - \log L_t) + gt + \theta_3 \log (Y/L)_{t-1}. \tag{12}$$

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.

Money Market

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

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

Whereas 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, taken 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:

$$\log \frac{M_t}{P_t} = \beta_0 + \beta_1 i_t + \beta_2 \log Y_t + \beta_3 \log Y_{t-1} + \beta_4 \log \frac{M_{t-1}}{P_{t-1}}. \tag{15}$$

The lagged term in Y allows for different speeds of adjustment of the demand for money to changes in interest rates and income.[9]

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 models of small open economies, 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, 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:

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

Here, $E_t e_{t+1}$ is the expectation at time t of the exchange rate in period $t+1$; $\tilde{\imath}_t$ is the interest rate that would prevail if the capital account were closed; and ϕ is a capital mobility index ranging between zero and unity. When $\phi = 1$, it is implied 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 $\tilde{\imath}$—that is, the rate that would emerge under a completely closed capital account. As ϕ increases from zero to unity, 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.

The interest rate that would prevail in an economy with a closed capital account (that is, one with no private capital flows), $\tilde{\imath}_t$, 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 by $\tilde{M}$) 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 $\tilde{\imath}_t$ can be obtained by solving the following equation:

$$\log\frac{\tilde{M}_t}{P_t} = \beta_0 + \beta_1 \tilde{\imath}_t + \beta_2 \log Y_t + \beta_3 \log Y_{t-1} + \beta_4 \log\frac{M_{t-1}}{P_{t-1}}. \tag{18}$$

[9] 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.

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 $\overline{M}_t$, is given by setting $i = \bar{i}$ in the money-market equilibrium condition (15).

Given $\overline{M}_t$ 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 rate. 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

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

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

Government

The model's dynamic specification is completed with a description of the behavior of the nonfinancial public sector. The public sector acquires assets in external markets ($F_{G,t}$) as well as from the domestic banking sector ($D_{G,t}$).[10] For its revenues it relies on tax receipts, T_t, and on 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

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

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. However, 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 that 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 world depends on the degree of 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 levels 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.

II. Estimation Issues

The equations to be estimated are (2), (5), (6), (7), (12), (15), and (16). These are repeated for convenience in Table 1. The approach to estimation used here assumes that the slope parameters do not change

[10] A negative value of $F_{G,t}$ denotes accumulated debt.

Table 1. Behavioral Equations of the Model

(2)	$\log C_t = \alpha_0 + \alpha_1 r_t + \alpha_2 \log C_{t-1} + \alpha_3 \log Y_t^d + \alpha_4 \log Y_{t-1}^d$
(5)	$I_t = k_1 (r_t - r_{t-1}) + k_2 (Y_t - Y_{t-1}) + k_3 I_{t-1}$,
(6)	$\log X_t = \tau_0 + \tau_1 \log \frac{e_t P_t^*}{P_t} + \tau_2 \log Y_t^* + \tau_3 \log X_{t-1}$
(7)	$\log Z_t = \delta_0 + \delta_1 \log \frac{e_t P_t^*}{P_t} + \delta_2 \log Y_t + \delta_3 \log \frac{R_{t-1}}{P_{t-1}^* Z_{t-1}} + \delta_4 \log Z_{t-1}$
(12)	$\log (Y/L)_t = \theta_0' + \theta_1 (K_t' - \log L_t) + gt + \theta_3 \log (Y/L)_{t-1}$
(15)	$\log \frac{M_t}{P_t} = \beta_0 + \beta_1 i_t + \beta_2 \log Y_t + \beta_3 \log Y_{t-1} + \beta_4 \log \frac{M_{t-1}}{P_{t-1}}$
(16)	$i_t = \phi \left(i_t^* + \frac{E_t e_{t+1} - e_t}{e_t} \right) + (1 - \phi)\, \bar{i}_t$

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 1963–87 for 31 developing countries[11] collected from the International Monetary Fund's *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 III.

Unobserved Variables

The first estimation issue to be confronted is the absence of data on the market-determined interest rate i_t and, of course, the shadow interest rate $\bar{i}_t$. In developing countries the relevant market-determined interest rate is typically that for loans in informal, or "curb" markets. Time-series data on such interest rates are very rare. Published developing

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

country interest rate data typically refer to central bank discount rates or to official interest rates on deposits or bank credit. Such interest rates have almost invariably been set by administrative fiat and do not adequately capture the marginal cost of funds.

This problem can be addressed by solving equation (18) for the shadow interest rate $\tilde{i}_t$, and then substituting the resulting expression for $\tilde{i}_t$ into (16) to solve for i_t. The result is an equation for the domestic market-determined interest rate that expresses this variable as a function of domestic money-market conditions as well as of the external interest rate. The solution for the nominal interest rate can be used to eliminate i_t from the money-demand function (15), permitting that equation to be expressed in terms of observable variables. The expression for i_t can also be substituted into (21) to solve for the real interest rate r_t. This solution for the real interest rate can be used to eliminate r_t from both the consumption function (2) and the investment function (5), rendering these equations in terms of observable variables. 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, as is common in much of the developing country literature, 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).

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 that prediction errors should be nonsystematic:

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

where $\epsilon_{i,t+1}$ is a serially uncorrelated random disturbance term. For estimation a reasonable proxy is needed 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 $E_t P_{i,t+1}$, according to equation (23), is the actual $P_{i,t+1}$. The associated estimation procedure must take account of the errors-in-variables problem implied by (23). This errors-in-variables method (EVM), 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, is a well-known approach to estimation under rational expectations.[12] 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.[13] Wickens (1982, 1986) emphasizes many advantages of the EVM approach over the SM method. He shows that in a nonlinear model such as ours, the additional nonlinearity in the parameters introduced due to SM will make the estimation technique hopelessly complicated. Wickens (1982, 1986) also demonstrates that EVM is in general more robust than SM in cases where the variables in the 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, advancing 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

$$P_{it+1} = \Pi \cdot X_{it} + \epsilon_{i,t+1}. \tag{25}$$

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 (that is, 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 nonlinear restrictions both within and across equations.

[12]See McCallum (1976), Lahiri (1981), and Wickens (1982). See also Blundell-Wignall and Masson (1985).
[13]See Hansen and Sargent (1980, 1981) and Wallis (1980).

Treatment of Country Heterogeneity

The use of pooled cross-section, time-series data means that the issue of country heterogeneity has to be confronted. Most studies that use such data for empirical estimation rely on a fixed-effects model, using dummy variables to deal with country heterogeneity, primarily for ease of estimation (see, for example, Khan and Knight (1981)). 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. The approach has the advantage that it recognizes the possibility that country-specific effects may be correlated across equations.

Method of Estimation

As is well known, variance-components characterization of country heterogeneity implies that generalized least-squares (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.[14] At the first stage, the vector of residuals was calculated from two-stage least-squares (2SLS) estimates of the model. These residual estimates were used to calculate the variance and covariance components. See Wallace and Hussain (1969) 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 (1982) and Sevestre and Trognon (1985) have shown that this estimator is consistent and, for dynamic models, independent of initial conditions. In our case, a generalized, nonlinear, three-stage-least-squares estimator was used due to the presence of nonlinearities 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

[14] For more detailed discussion of estimation with variance components see Balestra and Nerlove (1966), Hausman and Taylor (1981), Amemiya and McCurdy (1986), Breusch, Mizon, and Schmidt (1989), and Maddala (1988).

(X_{ji}); they have shown that the use of this procedure allows efficient estimation in models with panel data.[15]

III. Model Estimates

The error-components, two-stage least-squares (EC2SLS) estimates form the basis for the implementation of the error-components, three-stage least-squares (EC3SLS) estimation (see Baltagi (1981)). The results of the EC3SLS estimation are presented in Table 2. As will be discussed below, these results indicate that the model fits the data very well. Almost all the estimates are of the right sign, and a large number of them are estimated precisely. In what follows we shall discuss the estimates of, and the hypotheses embedded in, each of the behavioral equations separately.[16]

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 (for example, the rate of inflation) may have contributed to this result.[17] The estimated coefficient is, however, quite small, suggesting that changes in interest rates would not induce substantial changes in con-

[15] Before estimating the model, we tested our assumed error-components structure, and also conducted tests for serial correlation. These tests are described in Haque, Lahiri, and Montiel (1990), which also provides a detailed treatment of estimation issues. The results were consistent with the variance-components model, and no signs of serial correlation were detected in the residuals.

[16] 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 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 (that is, 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.

[17] See Giovannini (1985) for a discussion of this issue.

Table 2. Nonlinear Error-Components, Three-Stage Least-Squares Estimates of Structural Parameters

Parameter	t-ratio
Consumption	
$\alpha_0 = 0.047$	5.62*
$\alpha_1 = -0.076$	−4.08*
$\alpha_2 = 1.010$	96.28*
$\alpha_3 = 0.143$	3.64*
$\alpha_4 = -0.149$	−4.23*
	$\bar{R}^2 = 0.997$
Investment	
$k_0 = -0.226$	−6.81*
$k_1 = -0.113$	−4.03*
$k_2 = 0.196$	9.74*
$k_3 = 0.809$	44.94*
	$\bar{R}^2 = 0.980$
Production function	
$\theta_1 = 0.122$	6.55*
$\theta_3 = 0.881$	63.38*
$g = 0.141$	6.49*
	$\bar{R}^2 = 0.979$
Exports	
$\tau_1 = 0.050$	2.05*
$\tau_2 = 0.084$	1.78*
$\tau_3 = 0.925$	82.24*
	$\bar{R}^2 = 0.983$
Imports	
$\delta_1 = -0.157$	−5.09*
$\delta_2 = 0.161$	6.02*
$\delta_3 = 0.038$	5.96*
$\delta_4 = 0.834$	43.21*
	$\bar{R}^2 = 0.977$
Money demand	
$\beta_0 = -0.146$	−4.36*
$\beta_1 = -0.038$	−1.27
$\beta_2 = 0.571$	3.99*
$\beta_3 = -0.397$	−2.79*
$\beta_4 = 0.881$	59.56*
	$\bar{R}^2 = 0.997$
Capital mobility	
$\phi = 1.004$	90.59**

Note: one asterisk (*) indicates parameter significance at the 5 percent level; two asterisks (**) indicate not significantly different from unity; and $\bar{R}^2$ denotes the coefficient of determination corrected for degrees of freedom.

sumption. 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 unity 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 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).

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 do not include interest rates as an explanatory variable because of lack of adequate information (see Blejer and Khan (1984a, 1984b)). Our approach to modeling 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 unity, 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.

Aggregate Supply

All the variables in the estimated aggregate supply (production) function are significant and of the right sign.[18] Since θ_0' contains log K_0, which

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

is an initial-value parameter representing the initial stock of capital for each country, equation (12) was estimated from the "within" dimension of the data. The parameter ρ was estimated to be 0.05, although estimates of θ_1, g, and θ_3 were not particularly sensitive to values of ρ in the vicinity of 0.05.[19] 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). Nevertheless, the supply equation provided the least satisfactory empirical results. The coefficient on the lagged dependent variable is implausibly high, suggesting that some of our maintained hypotheses (for example, regarding the form of the production function or the degree of wage-price flexibility) require further investigation.

Foreign Trade

The estimated export function fits the data well, with all coefficients bearing the expected signs and reasonable magnitudes. The fitted equation exhibits a significant export response to relative price changes, although one that is somewhat smaller in magnitude than other available estimates.[20] 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) function for the demand for exports, 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 the estimated coefficients also 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).

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

[20]See Khan (1974), Goldstein and Khan (1985), and 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, when these results are being compared, 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.

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 −0.04 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.[21]

As described above, our modeling approach and method of estimation allow 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 unity, suggesting that capital was in effect highly mobile for these countries over our sample period. This result supports the validity of the small-open-economy approach to modeling the financial sector in developing economies and implies that economic agents readily find ways to get around official barriers to capital mobility. Thus, the uncovered interest parity condition can be used to proxy for interest rates in modeling developing economies.[22,23]

IV. Conclusions

This paper attempts to fill a void in empirical developing country macroeconomies. There is at present no consensus on "representative"

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

[22] 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 were essentially unchanged, with the exception of the consumption function. This function exhibited a substantially greater interest rate elasticity. The estimated fraction of liquidity-constrained households was about one third, a result which is much closer to the estimates in Haque and Montiel (1989).

[23] Evidence in favor of a high degree of capital mobility was also found in Haque and Montiel (1990a, 1990b).

developing country values of the parameters of key macroeconomic behavioral relationships. Although 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 and open developing economy. The model itself is innovative only in that expectations are formed rationally and 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 macroeconomic analysis of developing countries. Its estimated parameters, presented in Table 1, generally conform to standard economic theory, and in many cases approximate those that are available in the literature. Unsatisfactory results emerged only with regard to the economy's supply function, and this suggests an important avenue for future research.

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—that is, it suggests that little leverage can be exercised on domestic aggregate demand through monetary policy in these countries, even though the effects of changes in credit policy on the balance of payments may be substantial. This degree of capital mobility is consistent with the episodes of massive capital flight that have been observed in a number of developing countries in recent years. Finally, although we were able to estimate substitution elasticities fairly 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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