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A MONETARY APPROACH TO THE CRAWLING-PEG SYSTEM: THEORY AND EVIDENCE

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With the advent of the modern literature on the monetary approach to the balance of payments and to the exchange rate, and following the seminal contributions of Mundell (1968, 1971), Johnson (1972), and Dornbusch (1973), a large amount of effort has been devoted to emphasizing the role of the money market, and of asset markets, in the determination of the balance of payments and the exchange rate. The long-run impact of monetary shocks in a regime of fixed exchange rates, the effects of devaluations and changes in commercial policy in a monetary setting, and the short-run consequences of monetary imbalance on the inflation rate and on the balance of payments have recently been the object of careful theoretical and empirical study. The importance of monetary variables in the determination of the exchange rate in a regime of floating rates has also been analyzed in detail.[1/]

1/ A number of important contributions on the topic are collected in Frenkel and Johnson (1976, 1978) and in the IMF (1977) volume. A review of the empirical evidence on the monetary approach to the balance of payments and exchange rates is presented in Magee (1976). Johnson (1977) and Whitman (1975) present comprehensive reviews of the recent contributions to the monetary approach literature, while a critique of some of the central aspects of that approach is elaborated by Hahn (1977). All these deal with fixed-exchange-rate regimes.

Among those dealing with floating rates are Dornbusch (1976), Frenkel (1976), Frenkel and Clements (1978), Kouri (1975), and Mussa (1976).

Most of these studies, however, have dealt either with cases in which the exchange rate has been kept fixed for very long periods, or with cases of free floating in which the exchange rate is predominatly determined by the interaction of market forces without government intervention.2/

Yet in recent years many countries have experienced simultaneous fluctuations in both their exchange rates and international reserves. These fluctuations have occurred either under a managed-float system, characterized by government intervention in the foreign-exchange market, or under a crawling-peg system, in which the authorities completely determine, and periodically change, the country's exchange rate.3/ In order to explicitly analyze the experience of countries with these characteristics, an extension to the previous formulations of the monetary approach is required.

2/ An exception is the study by Girton and Roper (1977). They develop and test a monetary model of exchange-market pressure, which is defined as a composite variable that includes changes in both the exchange rate and international reserves. As will be seen below, our model deals with the simultaneous determination of each of the components of exchange-market pressure.

3/ A theoretical analysis which concludes that the optimal exchange rate regime will correspond to neither of the extremes of a completely fixed or a completely flexible rate is presented by Frenkel (1978, Appendix C). Frenkel, then, concludes that "....for the purpose of empirical work it is useful to design a framework of the adjustment mechanism that can accommodate simultaneously changes in international reserves and changes in the exchange rate." [Frenkel (1978, p. 39, fn. 1)].

In this paper we develop and estimate a framework, which extends the monetary approach, for the analysis of the joint determination of the exchange rate, international reserves, and the rate of inflation when a crawling-peg system is adopted. The basic model is presented in Section I. In the same section, we utilize the model to study the impact of changes in domestic monetary policy on the evolution of these three endogenous variables. The empirical implementation of the model, presented in Section II, uses quarterly data from Brazil for the crawling-peg period: 1968 III-1977 IV. We estimate the parameters of the model simultaneously using a Full-Information Maximum-Likelihood method. Concluding remarks are presented in Section III.

I. THE MODEL

Monetary Equilibrium.

The model here developed is a variant of the monetary approach to the balance of payments. Its main feature is that it accounts for different degrees of exchange-rate flexibility (from a freely floating parity to a totally fixed exchange rate). We take the case of a small country, defined as one the international price of whose traded goods is exogenously determined, and we allow for the existence of nontraded goods defined as goods whose price responds, at least in the short run, to domestic monetary variables.

We also assume that the rate of growth of real income is not affected by monetary variables.

The basic relationships of the monetary sector are:

(1) $M_s \equiv a(R + D)$

(2) $M_d = Pm_d$

(3) $m_d = f(y, \pi^e)$,

where M_s is the nominal supply of domestic money; a is the money multiplier; R is the foreign-exchange reserves held by the Central Bank; D is the domestic-credit component of the monetary base; M_d is the demand for nominal cash balances; P stands for a price index that includes traded and nontraded goods; and m_d is the real demand for money, which is assumed to be a function of real income, y, and of the alternative cost of holding money, proxied by π^e the expected rate of inflation. 4/

Although it is possible to postulate a mechanism of lagged adjustments, 5/ for simplicity we assume the existence of stock equilibrium during the period of analysis, i.e., that the money market clears in each period so that the nominal stock of money

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4/ As it happens, the results below are valid under a large variety of assumptions about the mechanism for the formation of π^e, provided that the latter depends on lagged variables. In the empirical application, we assume that π^e is formed by a version of rational expectations; see Section II.

5/ Indeed, in Section II we postulate for the empirical analysis a mechanism of lagged adjustments in the money market.

is equalized, ex-post, with the demand for nominal balances. The assumption requires the existence of the flow equilibrium

$$(4) \qquad M_s^* = M_d^*,$$

where the asterisk indicates the percentage rate of change of the variable. Differentiating equations (1) and (2) logarithmically, the flow-equilibrium condition can be rewritten as

$$(4') \qquad a^* + (1 - \gamma) R^* + \gamma D^* = P^* + m_d^*,$$

where γ is a factor of proportionality equal to $D/(R + D)$ and P^* is the domestic rate of inflation.

The Domestic Rate of Inflation and the Balance of Payments.

When traded and nontraded goods are both present, the domestic rate of inflation can be measured as a weighted average of the rate of change of the price of both kinds of goods,

$$(5) \qquad P^* = \lambda P_T^* + (1 - \lambda) P_{NT}^*,$$

where P_T is the price of traded goods in domestic currency, P_{NT} is the price of nontraded goods, and λ is the share of traded goods in total expenditure. In a small economy P_T^* is determined by the world rate of inflation (P_w^*) and by the variations in the effective exchange rate (ρ^*):

$$(6) \qquad P_T^* = P_w^* + \rho^*.$$

The price of nontraded goods, however, may be affected by domestic factors, at least in the short run. Since an ex-ante excess supply of money implies excess demand in the goods market, and if excess demand for nontraded goods varies monotonically with excess demand throughout the economy, we can expect the price of nontraded goods relative to that of traded goods to be a function of imbalance in the money market,

$$(7) \qquad P^*_{NT} = P^*_T + \theta\Omega,$$

where Ω is a measure of monetary imbalance and θ is the elasticity of the relative price with respect to the monetary variable.[6/]

Regarding the measure of Ω, it is important to remember that a central conclusion of the monetary approach to the balance of payments is that in a small open economy the nominal supply of money may be beyond the control of the monetary authority. Under fixed exchange rates the monetary authority can only determine the ex-ante quantity of money by changing the domestic-credit component of the base, or to affect the money multiplier by manipulating variables under its control (such as legal reserve requirements). Such actions, in conjunction with the flow demand for real balances generated by adjustments in the desired stock, create an ex-ante excess flow supply of money to which the public reacts by changing the level of the international reserve component of the base through the balance

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6/ θ is a function of the elasticity of substitution between traded and nontraded goods in consumption and production as well as the income elasticity of the nontraded goods. For a detailed description of the dynamics of domestic-price determination in a monetary model with traded and non-traded goods, see for example Blejer (1977) and Parkin (1974).

of payments and by affecting the rate of domestic inflation. The ex-post nominal quantity of money in an open economy is then influenced by the behavior of the public in response to ex-ante conditions in the money market.[7/]

It appears, therefore, that the relevant measure to account for the monetary effects on the goods market in an open economy should be an ex-ante measure which does not include the endogenous reaction of the foreign component of the base. For that reason we define Ω in equation (7) as the gap (in percentage terms) between the ex-ante change in the money supply (i.e., a change in the domestic-credit component of the base and in the money multiplier) and changes in demand. Equation (7) can therefore be rewritten as

$$(7') \qquad P^*_{NT} = P^*_T + \theta(\gamma D^* + a^* - M^*_d).$$

Substituting (6) into (7') and then (6) and (7') into (5) we obtain, after some manipulation, the following expression for the rate of domestic inflation:[8/]

$$(8) \qquad P^* = \varepsilon(P^*_w + \rho^*) + (1 - \varepsilon)(\gamma D^* - m^*_d),$$

where $\varepsilon = 1/[1 + \theta(1 - \lambda)]$.

7/ For time-series analysis and econometric tests of the interaction between changes in domestic credit and in international reserves implied by the monetary approach using European data, see Blejer (forthcoming), and Leiderman (1978).

8/ Assuming, for simplicity, a constant money multiplier, i.e., $a^* = 0$. In the empirical section, however, changes in the money multiplier are explicitly considered.

In addition to changes in the price level, there are also changes in international reserves operating to restore monetary equilibrium. Therefore an expression for the money account of the balance of payments, which is equal to the change in the international reserves held by the Central Bank, may be obtained by substituting P* in equation (4')--the flow equilibrium condition for the money market--for its value in (8) and rearranging the terms:

$$(9) \qquad (1 - \gamma)R^* = \varepsilon(P^*_w + \rho^* + m^*_d - \gamma D^*).$$

Equations (8) and (9) present the domestic rate of inflation and the balance of payments as functions of world inflation, exchange rate policy, and the rate of ex-ante excess flow supply of money. When nontraded goods are absent ($\lambda = 1$) or when their price is not sensitive to monetary imbalance ($\theta = 0$), then $\varepsilon = 1$ and the model is similar to the classical long-run formulation of the monetary approach (see Johnson (1972)). In such case, domestic monetary variables do not affect the domestic rate of inflation which, if the exchange rate is not altered, is fully determined by the world rate, and every ex-ante monetary shock will lead to reserve depletion due to a balance-of-payments deficit.

The Endogeneity of the Exchange Rate in a Crawling-Peg System.

Except in a fully flexible exchange-rate system (or in a managed float), the exchange rate is regarded by governments as a policy instrument, and its fluctuations are generally influenced by policy decisions aimed at one or more policy goals. Unlike under an adjustable-peg regime, under a crawling-peg system the exchange rate is changed frequently according to some set of rules adopted in order to attain the government's objectives. 9/ The variations of the exchange rate can therefore be considered as following a sort of reaction function which reflects policy goals as well as the parameters of the model adopted and the values of the exogenous and endogenous variables considered relevant for the desired goals. These goals, and therefore the crawling rules, may vary from country to country. 10/

With a view towards empirical implementation of the model for the case of Brazil, we shall postulate here that the policy objective is to avoid long-run changes in the real exchange rate and that the nominal rate (ρ) is therefore altered to maintain purchasing power parity. 11/ We assume, in addition, that the full adjustment of the

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9/ A number of porposals for the operation of the crawling-peg as well as analyzes of the stability of the system have recently been presented in the literature. See for example Cooper (1970), Kenen (1975), Levin (1975, 1977), Mathieson (1976), and Williamson (1965).

10/ Kenen (1975) analyzes in detail the relative efficiency of a number of alternative sliding-parity rules. Mathieson (1976) studies the consequences of using a welfare--instead of a balance-of-payments--objective as the guideline for the crawl.

11/ A discussion of the appropriateness of this assumption for the case of Brazil is presented in Section II below.

In a previous version of this paper a number of alternative rules were incorporated into the model, among them maintaining a given level of nominal reserves ($R^* = 0$) and maintaining a given level of real reserves ($R^* - P_W^* = 0$). Although the dynamics of the system change with the policy rule, its basic structure is not affected. For presentational convenience the functioning of the model is here confined to a single rule.

exchange rate may take more than one period and we shall analyze the effects of differences in the speed of exchange-rate adjustment. The reaction function implied by the policy rule is

$$\rho^*_t = \beta \sum_{i=0}^{n} (1 - \beta)^i L^i (P^* - P^*_w)_t, \qquad (10)$$

where t is a time subscript; β indicates the portion of the current differential rate of inflation transmitted to the exchange rate in the current period and L is the lag operator (such that $L^i x_t = x_{t-i}$).12/

This formulation specifically assumes that (in addition to the current-period adjustment) the exchange rate will continue to be changed in each subsequent period by a portion β of the still unadjusted differential until the whole differential has been transmitted to the exchange rate. Obviously, the greater is β, the faster will be the adjustment of the rate. If β = 1 our model does not differ conceptually from the monetary-approach model of free floating exchange rates, since the rate of depreciation is then fully determined by the domestic-foreign inflation differential (see Frenkel (1976)).

12/ A reaction function of this type follows the approach of Dean (1974) in the sense that endogenous target variables are functions of the current values of other endogenous variables on the grounds that they are a plausible representation of the structure of the model allowing for the possibility of prior knowledge of the structural-form coefficients. This differs from the approach of earlier works such as Friedlaender (1973) where endogenous variables depend only on exogenous or lagged-endogenous variables.

The Functioning of the Model.

We proceed now to solve the model for the three endogenous variables in which we are interested: the rate of inflation, the rate of change of foreign-exchange reserves, and the rate of change of the exchange rate. Combining (8) and (10) to solve for ρ^*_t we obtain

$$(11) \qquad \rho^*_t = \frac{\beta(1-\varepsilon)}{1-\beta\varepsilon-(1-\beta)L}(\gamma D^* - m^*_d - P^*_w)_t \quad ,$$

and substituting this in (8) and (9), we obtain

$$(12) \qquad P^*_t = \frac{\varepsilon\left[(1-\beta)(1-L)\right]}{1-\beta\varepsilon-(1-\beta)L}(P^*_w)_t + \frac{(1-\varepsilon)(1-(1-\beta)L)}{1-\beta\varepsilon-(1-\beta)L}(\gamma D^* - m^*_d)_t \ ,$$

and

$$(13) \qquad (1-\gamma)R^*_t = \frac{\varepsilon\left[(1-\beta)(1-L)\right]}{1-\beta\varepsilon-(1-\beta)L}(P^*_w + m^*_d - \gamma D^*)_t \ .$$

The three endogenous variables are functions of current and lagged values of foreign inflation and of domestic monetary variables. We can consider now which type of monetary policy will equalize the domestic rate of inflation to the world rate. Because the coefficients of P^*_w and $(\gamma D^* - m^*_d)$ in equation (12) add to unity, P^* will equal P^*_w when the monetary authority expands the money supply at the rate necessary to satisfy the growth in real demand and to replace the depreciated value of the nominal stock. This is achieved when the exogenous component of the supply of money (domestic credit) is expanded at a rate that exceeds the growth in the demand for real balances by the world rate of inflation, i.e., when the ex-ante excess flow supply of money is equal to the world inflation rate:

$$(14) \qquad (\gamma D^* - m_d^*) = P_w^*,$$

which implies

$$(15) \qquad P^* = P_w^*$$

and

$$(16) \qquad p^* = R^* = 0.$$

To illustrate further the functioning of the model we can analyze the effects of a domestic-credit shock. To do so, it is convenient to consider an economy whose initial equilibrium satisfies equations (15) and (16) above. Starting from such position of equilibrium, and as long as β and ε are smaller than unity, an acceleration in the rate of expansion of the domestic-credit component of the monetary base, $\Delta(\gamma D^*)$, will cause the rate of domestic inflation to depart from the world rate (here assumed constant), the exchange rate will rise and a balance-of-payments deficit will be created.

If the rate of growth of domestic credit is sustained at the new, higher, level the exchange rate will eventually adjust to account fully for the differential in the inflation rates, which will then be equal to $\Delta(\gamma D^*)$.[13] Once the changes in the exchange rate fully reflect the differential rate of inflation, the whole excess supply of money created by the government in each period is fully eliminated through an increase

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13/ That is, the difference between the new rate of ex-ante excess supply of money $[\gamma D^* + \Delta(\gamma D^*) - m_d^*]$ and the world rate of inflation.

in domestic prices, and no further flows of foreign exchange reserves occur. This process is illustrated in Figure 1 for different values of β and ε.[14/]

Certainly, as β increases, for given values of ε, the exchange rate adjusts faster to the monetary shock, domestic inflation both diverges faster from world inflation and converges faster to its new equilibrium rate. As can be observed by comparing paths III and II in Figure 1, the balance of payments deteriorates less and returns to equilibrium more rapidly (implying a small total loss of reserves) as β increases. When $\beta \to 1$, the system approaches a flexible-exchange-rate model, like the one presented by Frenkel (1976), in which domestic inflation is always independent of world inflation and the balance of payments is always zero. Letting $\beta = 1$ in equations (11)-(13), we obtain:

(17) $$P^*_t = (\gamma D^* - m^*_d)_t ,$$

(18) $$\rho^*_t = (\gamma D^* - m^*_d - P^*_w)_t = (P^* - P^*_w)_t ,$$

(19) $$R^*_t = 0 .$$

The speed of adjustment will also increase, for given values of β, the lower is ε, i.e., the higher the share of nontraded goods in expenditures, λ, or the higher the elasticity of relative prices with

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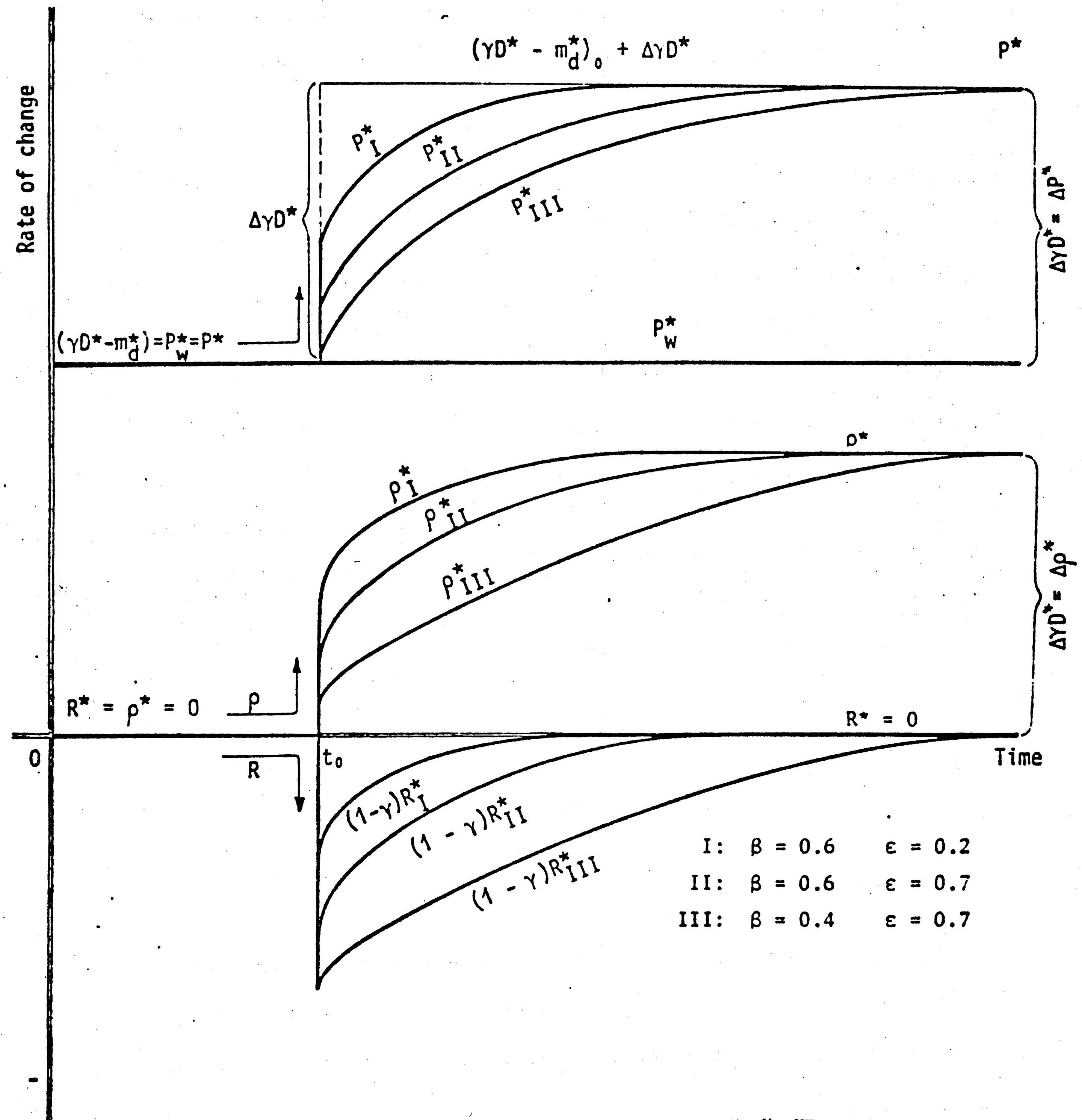
14/ For presentational simplicity the figure does not consider the effects of the temporary reduction in m^*_d as inflationary expectations accelerate. The pattern of adjustment is, however, very similar when these effects are taken into account.



Rate of change
(γD* - m*d)o + ΔγD*
P*
P*I
P*II
P*III
ΔγD*
ΔγD* = ΔP*
(γD*-m*d)=P*w=P*
P*w
ρ*
ρ*I
ρ*II
ρ*III
ΔγD* = Δρ*
R* = ρ* = 0
ρ
R* = 0
0
R
t0
Time
(1-γ)R*I
(1 - γ)R*II
(1 - γ)R*III
I: β = 0.6 ε = 0.2
II: β = 0.6 ε = 0.7
III: β = 0.4 ε = 0.7

Figure 1

respect to monetary imbalance, θ. The more rapid adjustment of the rate of exchange when ε falls (which also implies a faster acceleration of the rate of inflation although a smaller loss of reserves during the adjustment process) is illustrated by the comparison of paths II and I in Figure 1.

The results obtained indicate, therefore, that under a crawling-peg system a small country can choose its own long-run rate of inflation independently from the rest of the world. Balance-of-payments deficits and surpluses are, however, experienced in the process of adjustment because of purchasing-power disparities arising from less than immediate full adjustment of the exchange rate.

We turn now to the analysis of the empirical results obtained by applying the model described above to the case of Brazil.

II. EMPIRICAL INVESTIGATION

Estimation Procedures.

In this section, the model developed above is restated in econometric form. For estimation purposes, we work with the following system:

(8') $$P_t^* = \varepsilon(P_w^* + \rho^*)_t + (1-\varepsilon)(a^* + \gamma D^* - \overset{*}{m}_d)_t + \mu_{1t}$$

(9') $$(1-\gamma)R_t^* = \varepsilon(P_w^* + \rho^* + \overset{*}{m}_d - \gamma D^* - a^*)_t + \mu_{2t}$$

(10') $$\rho_t^* = \beta(P^* - P_w^*)_t + \beta(1-\beta)(P^* - P_w^*)_{t-1} + \beta(1-\beta)^2(P^* - P_w^*)_{t-2} + \mu_{3t}$$

Equations (8'), (9'), and (10') could be referred to as the model's "semi-structural" equations.[15/] These equations correspond, with only slight modifications,[16/] to equations (8), (9), and (10) above.

The following stochastic specification is adopted: it is assumed that the μ's possess a first-order autoregressive representation

$$\mu_{it} = \phi_i \mu_{it-1} + v_{it} \qquad i = 1, 2, 3$$

where ϕ_i are the autoregressive parameters, and v_{it} are error terms. Furthermore, we assume that the error vectors (v_{1t}, v_{2t}, v_{3t}), $t = 1\ldots T$, have zero mean and a constant variance-covariance matrix Γ; also, they are serially uncorrelated and drawn from a multivariate normal distribution.

Equations (8'), (9'), and (10') constitute a simultaneous system, which is linear in the variables but nonlinear in (some of) the parameters. Given these characteristics, consistent estimation requires the use of some simultaneous-equation method. We have used a Full Information Maximum Likelihood (FIML) estimator. FIML utilizes all the a priori restrictions on the system to estimate the coefficients of interest, $(\varepsilon, \beta, \phi_1, \phi_2, \phi_3)$ in our case, by maximizing the model's likelihood function.[17/]

15/ This is so because (8') and (9') do not represent "truly" structural equations in the sense of autonomous behavioral equations. Equation (10'), however, is one of the model's structural equations.

16/ Specifically, random disturbances have been added, and we are now taking into account changes in the money multiplier. Also, we consider only three terms in the exchange rate equation (on this issue, see further discussion below).

17/ See Hendry (1971). The parameter estimates reported below were obtained by using Wymer's (1978) computer program Resimul. The program uses a Newton-Raphson iterative procedure, beginning with arbitrarily given initial values of the parameters.

To make the estimation operational, time-series for m^*_{dt}, the rate of change of real money demand are required. Here we have assumed a semi-logarithmic money demand equation, whereby the log of demand for real money balances depends, as in equation (3) above, on the log of real income and on expected inflation. As the model is applied to quarterly data, we postulate a process of gradual adjustment of real money balances to their optimal value.[18/] With these specifications, it is appropriate to take the first-differences of the fitted values of the estimated money demand equation as corresponding to the variable $m^*_{d_t}$.[19/] Finally, the estimation of money demand requires a proxy for π^e. This proxy was constructed by assuming a version of Sargent's (1973) "partly rational" expectations. Specifically, it is postulated that agents form their inflation expectations on the basis of least-squares predictions of inflation which are conditional on lagged rates of inflation.[20/]

18/ Formally, the demand for money is given by $\log m_{dt} = \delta_0 + \delta_1 \log y_t - \delta_2 \pi^e_t$. Money demand equations of this form have been previously estimated for Brazil by Silveira (1973) and Khan (1977). We assume an adjustment mechanism of the form $(\log m_t - \log m_{t-1}) = h\ (\log m_{dt} - \log m_{t-1})$, $0 < h < 1$. See Griliches (1967) for a discussion of the conditions under which adjustment mechanisms of this class are likely to be optimal.

19/ Although it is possible to think of the complete system as being composed of equations (8'), (9'), (10') and, in addition, (3), it will be noted that such system is block-recursive, with (3) forming the lowest-order block. Therefore, this equation can be consistently estimated at a first stage, even if its disturbance is contemporaneously correlated with those of (8'), (9') and (10'). This is the strategy adopted here.

20/ That is, $\pi^e = \sum_{i=1}^{n} \hat{\Psi}_i P^*_{t-i}$, where $\hat{\Psi}_i$ are the estimated parameters of this least-squares regression equation. In the empirical application we set $n = 6$.

Before we turn to a discussion of the empirical results, it is well to present a brief discussion of the Brazilian conditions during the crawling-peg period 1968-1977.

A Crawling-Peg Experience: The Case of Brazil.

Brazil's adoption of the crawling-peg regime can be considered as an extension of indexation to the external sector. Starting in 1964, Brazil engaged in one of the most comprehensive indexation programs anywhere. Financial and labor markets were the first to be indexed. By August 1968 exchange-rate indexation was introduced. 21/

During the post-war period Brazil had experienced with a variety of exchange rate regimes. Until 1953, exchange controls and licensing were widespread. In 1953 an exchange auction system with multiple exchange rates was introduced. A process of unifying the rates was initiated in 1961, and since then the country had a pegged exchange rate. Since 1968, when the crawling peg was adopted, the central bank announces, at very frequent intervals, 22/ new selling and buying rates for the cruzeiro in relation to the U.S. dollar.

21/ On the various aspects of indexation in Brazil, see the N.B.E.R. volume edited by Nadiri and Pastore (1977). A comprehensive study of the recent Brazilian economic experience is presented by Lemgruber (1977). On the functioning of the crawling peg and its effects on the economy, see Moura da Silva (1977). See also Lara Resende (1978).

22/ The rate was changed, on average, over ten times a year.

Despite the fact that there are no explicitly announced rules for the crawl, it is evident that the mechanism used is an application of a purchasing-power-parity clause to the domestic price of foreign exchange. The evolution of both domestic and foreign price levels is taken into account in making the adjustments of the exchange rate. In this way, and as emphasized by the Brazilian authorities, it is possible to neutralize the harmful effects of domestic inflation on the competitiveness of Brazilian products in international markets, and hence on Brazil's balance of payments. 23/

Although inflation differentials are certainly important factors in determining the crawl, they were not the only ones. However, it is evident from the data (see Lemgruber ((1977), Tables 1 and 6), and Moura da Silva ((1977), Table 2)) that the variations in the exchange-rate since 1968 have followed purchasing-power-parity rates closely, suggesting that exchange-rate changes have been mainly determined by the difference between domestic and foreign inflation. The specification of the exchange rate reaction function above (equation (10)) intends precisely to capture this feedback process. Such specification imposes restrictions on data; econometric tests of these restrictions as well as the results from estimating the model are reported in the following section.

23/ This appears to be the main rationale provided by the authorities for the adoption of the crawling-peg. On this issue see Lemgruber (1977) and Moura da Silva (1977).

Empirical Results.

In this section we report estimates of the parameters of (8'), (9'), and (10'), as well as of the derived reduced form equations. All estimates are based on quarterly data for Brazil. The sample period, 1968-III through 1977-IV, contains 38 observations. Most of the variables are represented by readily available series.[24/]

As mentioned before, the estimation of the model's semi-structural equations ((8'), (9') and (10')) requires the construction of the $m^*_{d_t}$ variable. Therefore, at a first stage we estimated a semi-logarithmic demand for money. The estimated equation is:

$$\log m_t = \underset{(0.195)}{-0.462} + \underset{(0.064)}{0.188} \log y_t - \underset{(0.283)}{1.665} \pi^e_t + \underset{(0.058)}{0.828} \log m_{t-1} ,$$

$$R^2 = 0.984 \qquad h = 1.12 \qquad RHO = -0.627 \qquad SE = 0.042.$$

Figures in parentheses are standard errors. To account for serial correlation in the residuals, the equation was estimated using the Cochrane-Orcutt technique. RHO is the estimated autocorrelation coefficient. h is Durbin's serial-correlation statistic for autoregressive models. SE is the standard error of the regression. π^e_t is our proxy for expecta-

24/ For P,R and M the following series were utilized: consumer price index, international reserves of the central bank, and the money supply. D was generated by substracting R from the monetary base. ρ is the exchange rate (average over the quarter). All the above were taken from International Financial Statistics, various issues. y is represented by the quarterly real-income series constructed by Wachter (1976). (The series were extended through 1977 using exactly Wachter's method.)

tions of inflation, formed with the fitted values of a sixth-order inflation autoregressive process.25/

All the coefficients in the estimated money-demand equation have the expected signs and are significantly different from zero. The estimated coefficients are fairly similar to those reported by Khan (1977) and Silveira (1973) for the case of Brazil. Our parameter estimates imply a long-run income elasticity of real money demand equal to 1.093, and a long-run elasticity or real money demand with respect to expected inflation of -0.57. Given these results, we constructed m^*_{dt} by taking the first difference of the fitted values of the estimated money demand equation.

Results of estimating (8'), (9') and (10') are presented in Table 1. All the parameter estimates are of the proper sign, and are reasonably well determined: in most cases asymptotic t-ratios are well

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25/ As noted above, this methodology can be interpreted as a version of Sargent's (1973) "partly-rational" expectations. The estimated equation is:

$$\pi^e_t = [\underset{(0.164)}{0.876} - \underset{(0.218)}{0.471}L + \underset{(0.225)}{0.488}L^2 - \underset{(0.220)}{0.041}L^3 + \underset{(0.204)}{0.039}L^4 - \underset{(0.150)}{0.125}L^5]P^*_{t-1} +$$

$$+ \underset{(0.009)}{0.012} + \underset{(0.008)}{0.011}S1 - \underset{(0.007)}{0.005}S2 - \underset{(0.008)}{0.001}S3$$

$R^2 = 0.652$ D.W. = 1.79 S.E. = 0.015

Standard errors appear in parenthesis. L is the lag operator, defined in the text. Si represent seasonal dummies (i= 1, 2, 3) .

above 2.[26/] The reported $\tilde{R}^2$ are quite satisfactory for equations (9') and (10'), considering that the model is estimated in first differences; the $\tilde{R}^2$ for equation (8'), however, is low.[27/]

The results indicate that both foreign inflation and excess supply in the money market significantly affect the determination of the domestic rate of inflation. These two factors, world inflation and monetary imbalance, also affect significantly the balance of payments as shown by equation (9'). Specifically, an acceleration in the rate of domestic-credit creation over and above the rate of growth in money demand will increase domestic inflation and reduce international reserves. The overall effect of such increase, however, cannot be established solely from equations (8') and (9'). This is so because the departure of domestic from world inflation will induce, as indicated by equation (10'), a depreciation of the exchange rate which in turn, in this simultaneous model, further raises the rate of inflation and reduces the rate at which foreign-exchange reserves are being depleted. In order to analyze the full effect of changes in the rate of growth of domestic credit (as well as in the other exogenous variables) reduced-form coefficients should be considered. These coefficients are reported below.

26/ Asymptotic t-ratios are defined as coefficient values divided by asymptotic standard errors.

27/ $\tilde{R}^2$ is defined as one minus the ratio of variance of structural residual to variance of endogenous variable. The meaning of these $\tilde{R}^2$ in simultaneous models is ambiguous at best.

Regarding equation (10')--the exchange-rate reaction function--the parameter estimates indicate that more than fifty percent of the foreign-domestic inflation differential is transmitted to the exchange rate within the current quarter, and an additional twenty-five percent in the following one. After only three quarters the full differential is completely reflected by the exchange-rate adjustment. In this context, it is important to note that equation (10') embodies a specific restriction regarding the effects of current and lagged values of the domestic-foreign inflation differential on the exchange rate. Specifically, a pattern of geometrically decaying weights was postulated. Indeed, the results reported in Table 1 are derived under the imposition of this restriction. To test the empirical validity of the restriction, we have estimated the system unrestricted, and a chi-square likelihood ratio test was constructed. In our case, the likelihood ratio obtains a value of 2.255, with two degrees of freedom. This value is smaller than the 95 percent chi-square critical value; that is, the sample information does not reject the restrictions embodied in (10') at the usual five percent significance level.

With the information contained in Table 1 it is possible to calculate the derived reduced-form estimates and their asymptotic standard errors. The model's reduced forms are given by equations (11), (12), and (13). The estimates of these equations with their corresponding standard errors, as they are implied by the structural estimates reported in Table 1, are

TABLE 1. FIML Estimates of the Model

$$(8') \qquad P_t^* = \underset{(0.019)}{0.955}\ (P_w^* + \rho^*)_t + \underset{(0.019)}{0.045}\ (a^* + \gamma D^* - m_d^*)_t$$

$$\tilde{R}^2 = 0.054 \qquad \phi_1 = \underset{(0.083)}{-0.015} \qquad C_1 = \underset{(0.002)}{0.002}$$

$$(9') \qquad (1-\gamma)R_t^* = \underset{(0.019)}{0.955}\ (P_w^* + \rho^* + m_d^* - \gamma D^* - a^*)_t$$

$$\tilde{R}^2 = 0.295 \qquad \phi_2 = \underset{(0.139)}{-0.365} \qquad C_2 = \underset{(0.002)}{0.017}$$

$$(10') \qquad \rho_t^* = \underset{(0.117)}{0.537}\ (P^* - P_w^*)_t + \underset{(0.009)}{0.245}\ (P^* - P_w^*)_{t-1} + \underset{(0.074)}{0.098}\ (P^* - P_w^*)_{t-2}$$

$$\tilde{R}^2 = 0.375 \qquad \phi_3 = \underset{(0.060)}{0.017} \qquad C_3 = \underset{(0.003)}{0.007}$$

$$\hat{\Gamma} = \begin{bmatrix} 0.00053 & & \\ 0.00047 & 0.00480 & \\ -0.00047 & -0.00059 & 0.00048 \end{bmatrix}$$

NOTE: See text for notation. Figures in parenthesis are asymptotic standard errors of regression coefficients. $\hat{\Gamma}$ is the estimated residuals' variance-covariance matrix. C_i, i = 1, 2, 3, are the estimated constant terms.

presented in Table 2.[28/]

The overall effects of current and lagged rates of excess money supply and of foreign inflation on the exchange rate, the domestic rate of inflation, and the balance of payments can be assessed from the coefficients of equations (11'), (12') and (13').[29/] The latter indicate that about thirty percent of the excess flow supply of money (the difference between the rates of growth of domestic credit and money demand) is transmitted to the inflation rate within a period of five quarters. To the extent that the rate at which the excess supply of money is created exceeds the foreign rate of inflation, the exchange rate will depreciate (by about fifteen percent of the difference, during the first five quarters) and international reserves will fall. Monetary equilibrium is therefore maintained by a combination of reductions in the real value of the nominal stock (due to the acceleration in the inflation rate), and reductions in the monetary base (through the loss of reserves).

The effects of foreign inflation on the three endogenous variables can also be analyzed from the estimates in Table 2. A higher rate of world inflation will reduce the rate of depreciation of the exchange rate, and will have a positive effect on the rate of accumulation of foreign reserves. It will, however, significantly raise the domestic rate of

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28/ Since in the empirical section we are taking into account changes in the money multiplier, Table 2 refers to equations (11'), (12') and (13') which include such changes.

29/ Although for illustration purposes only current and four lagged coefficients are reported, the coefficients for additional lags can be calculated from the information provided in Table 1.

inflation during the current quarter. Notice that lagged rates of foreign inflation appear with a negative sign, which is indeed consistent with our version of the crawling-peg regime. An acceleration of world inflation will tend, *ceteris paribus*, to induce subsequent appreciations of the exchange rate, thus attenuating the initial increase in both the domestic price of traded goods and the domestic rate of inflation.

Table 2

Derived Reduced-Form Estimates

$$(11') \quad \rho_t^* = \underset{(0.018)}{[0.050} + \underset{(0.013)}{0.026L} + \underset{(0.012)}{0.024L^2} + \underset{(0.011)}{0.023L^3} + \underset{(0.010)}{0.022L^4}](\gamma D^* + a^* - m_d^* - P_w^*)_t$$

$$(12') \quad P_t^* = \underset{(0.029)}{[0.907} - \underset{(0.015)}{0.045L} - \underset{(0.014)}{0.043L^2} - \underset{(0.012)}{0.041L^3} - \underset{(0.011)}{0.039L^4}](P_w^*)_t +$$

$$+ \underset{(0.029)}{[0.093} + \underset{(0.015)}{0.045L} + \underset{(0.014)}{0.043L^2} + \underset{(0.012)}{0.041L^3} + \underset{(0.011)}{0.039L^4}] (\gamma D^* + a^* - m_d^*)_t$$

$$(13') \quad (1-\gamma)R_t^* = \underset{(0.029)}{[-0.907} + \underset{(0.015)}{0.045L} + \underset{(0.014)}{0.043L^2} + \underset{(0.012)}{0.041L^3} + \underset{(0.011)}{0.039L^4}](\gamma D^* + a^* - m_d^* - P_w^*)_t$$

Note: For notation and explanations see text.

III. CONCLUDING REMARKS

The purpose of this study has been to construct and test a model that accounts for the joint determination of the exchange rate, the rate of inflation, and the balance of payments in a crawling-peg economy. The model presented extends the previous literature on the monetary approach to the case of a crawling-peg exchange rate regime.

According to the model, a small open economy that indexes its exchange rate through the adoption of a purchasing-power-parity clause may choose its rate of inflation independently from the rest of the world. To the extent that purchasing-power disparities arise due to less than immediate full adjustment of the exchange rate, equilibrating flows of international reserves will take place. Thus, the model is capable of generating a pattern of short-run deviations from purchasing-power-parity, that occur simultaneously with movements in both international reserves and the exchange rate.

Our theoretical framework can be utilized in order to analyze the effects of domestic monetary policy and of external inflation on a crawling-peg economy. For example, we have shown that an increase in the rate of domestic-credit creation will generally tend to raise domestic inflation, reduce international reserves, and depreciate the exchange rate. The exact path of adjustment will depend on a number of parameters explicitly incorporated into the model. The faster the adjustment of the exchange rate to purchasing-power disparities is, for example, the greater the impact effects of domestic monetary variables on the rate of inflation, and the smaller their impact on the balance of payments. Similarly, domestic monetary variables will have a greater impact effect on domestic inflation, and a smaller effect on the balance of payments, the higher the share of non-traded goods in expenditures, and the higher the elasticity of the traded/non-traded relative price with respect to these monetary variables.

The basic equations of the model were estimated simultaneously, by Full Information Maximum Likelihood, on quarterly data for Brazil over the 1968 III-1977 IV crawling-peg period. The predictions of the model regarding signs and magnitudes of the different parameters appear to be sustained by the data. Overall, the empirical evidence presented seems to indicate that our theoretical framework is consistent with the sample information.

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