Speculative Attacks and Exchange Rate Crisis in Argentina 1979-1981

by

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Abstract: Exchange rate systems in Latin American countries, such as Argentina, have been frequently subjected to 'speculative attacks' which are events in which private agents discard their holdings of a currency in whose value they have lost confidence. Massive speculative attacks can often cause exchange rate systems to collapse. This paper develops a framework for predicting the breakdown of Argentina's crawling peg system in 1981. The lesson learned is that underlying inconsistencies between monetary and public debt policies led speculative attacks to occur and force the Argentinean authorities to abandon the crawling peg system.

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I. Introduction

Speculative attacks and collapsing exchange rate regimes have formed an important theoretical niche in the open macroeconomics literature.[1] Argentina's experience during 1979 to 1981 provides some empirical evidence for both applying and testing this literature. During this period, exchange rate movements were announced months in advance, as specified by a table of "daily" rates. Officially, Argentina's exchange rate system was classified as a crawling peg. The system broke down in 1981 because of massive speculative attacks - that is, agents swapping domestic currency for foreign owing to a loss of confidence in the domestic currency. The collapse of the system led to higher rates of domestic inflation.

The purpose of this paper is to analyze this particular episode in Argentina's history. Typically a fixed exchange rate system survives as long as the Central Bank has enough reserves to defend a particular parity. However, when a speculative attack against the domestic currency occurs with such force that the Central Bank exhausts its supply of reserves, the policy authorities abandon the fixed exchange rate system. The post-collapse exchange rate regime can be either a floating exchange rate system or another, but more sustainable, fixed exchange rate system.

The viability of a fixed or crawling peg system is important because policy-makers often wish to achieve price stability when they choose such a system. The possibility of collapse means that their price objectives will be less than effectively achieved, if at all. In 1978, the Argentinean government wanted drastically to reduce inflation[2] (see Table 1). A first step was to regain the confidence of the private sector. To this end, the government opted for a crawling peg system in which exchange rate changes would be announced in advance, enabling private agents to operate under a climate of greater policy certainty. Policy rules or commitments were looked upon more favorably than policy discretion.

The viability of an exchange rate system, however, requires that monetary and fiscal policies be consistent with the exchange rate regime in place. Underlying inconsistencies between monetary and fiscal policies have been cited as causing the collapse of exchange rate regimes in Mexico, Chile, France, and Italy. Similar factors were also at work in Argentina. During the early stages of the crawling peg regime, the Argentinean money supply grew rather slowly but the public sector financial deficit grew rapidly as a proportion of GDP. As Sargent-Wallace (1981) point out, an inconsistency arises because if the growth rate of public debt exceeds the growth rate of the economy, eventually the policy authorities would have to print money to finance the public debt since slow economic growth would not permit the financing of debt by further public borrowing or by raising taxes. Printing money raises seignorage revenue (that is, inflation taxes). Expectations of future inflation would impact immediately on private agents who are forward-looking. Private agents often respond to news of future inflation by engaging in speculative attacks against the domestic currency. This puts pressure on the domestic currency to depreciate in value. However, to maintain the value of the domestic exchange rate at its prespecified level, the Central Bank sells its holdings of foreign exchange reserves. When enough reserves are depleted, the country withdraws from the exchange rate system to prevent further drainage. Thus, the important link in the above scenario is that inconsistent monetary and fiscal policies lead speculators to lose confidence in the viability of an exchange rate regime, and their actions in turn help precipitate the collapse of a regime.

In this paper I use censored regression analysis to predict the breakdown of the crawling peg regime in Argentina. The probability of breakdown is a function of the inconsistencies reflected in the market 'fundamentals'. Essentially I use a simple model to determine what the exchange rate should be in the absence of a fixed exchange rate system (which I call the 'shadow' exchange rate) and compare that rate to the actual, prespecified rate. If the actual rate is overvalued relative to the shadow rate, speculators (who know the model) would know that the existing exchange rate system is unsustainable and realize that it is optimal to 'attack' it. The shadow rate shows signs of overvaluation when underlying policy variables show signs of long run inconsistency. The censored regression framework permits the analysis of both the actual exchange rate, which is observable, and the shadow exchange rate, which is unobservable.[3]

The plan of this paper is as follows. Section II presents the exchange rate model that is estimated. Section III describes the data and sample period. Section IV describes the estimation framework, methodology, and results. Section V reports on tests of the model (namely Wald, Specification, and Serial Correlation Tests). Section VI conducts some exercises with the results, such as reconstructing the probabilities of speculative attack and simulating the conditional and unconditional magnitudes of exchange rate changes. Section VII contains concluding remarks and suggestions for further research.

II. Model

Before presenting the model, I shall briefly discuss how speculative attacks are to occur in the model. At each instant in time, a "shadow" floating exchange rate can be calculated, which is the exchange rate that would prevail if the crawling peg or fixed exchange rate regime were abandoned at that instant. The econometrician cannot observe the shadow rate, but can use the model's unconstrained solutions to infer it. The shadow rate by definition is only observable when the system ends - that is, when the exchange rate constraint is relaxed and the rate is allowed to float freely. Based on the fundamentals that drive the floating rate, the econometrician is able to estimate the censored shadow rate in the presence of a crawling peg or fixed exchange rate regime.

Using 'absence of arbitrage opportunity' arguments, I will argue that a speculative attack should occur the moment the shadow exchange rate coincides with the fixed rate. Let $s(t)$[4] denote the shadow exchange rate at time t and $\bar{s}$ the fixed rate. Suppose that t^* represents the date at which a speculative attack occurs. If $s(t^*) > \bar{s}$, rational agents at an earlier date $t < t^*$ would have foreseen a profitable opportunity at t^* and acted earlier to preempt competitors in purchasing Central Bank reserves. That is, they could have purchased reserves for a price of $\bar{s}$ at time $t < t^*$, resold them for a price of $s(t^*)$ at time

t^*, and earned a windfall of $(s(t^*) - \bar{s})$. If all speculators had acted this way, the attack would have taken place earlier than t^*, which contradicts the assumption that the attack occurs at t^*. Hence the attack should occur precisely when $s(t^*) = \bar{s}$.

In a deterministic environment, agents would know at the start of a fixed exchange rate system whether the shadow rate will ever cross the fixed rate. It is therefore assumed that agents operate in a stochastic environment, but have rational expectations.

The following model represents a small open-economy. It is essentially a monetary model in which I allow for deviations in purchasing power parity (PPP) and for a fiscal side to link money creation and government budgetary deficits. All lower case lettered variables are in logs:

(1) $$m_t - p_t = \alpha_0 - \alpha_1(E_t p_{t+1} - p_t) + e_{1t}$$

(2) $$p_t = p_t^* + s_t + e_{2t}$$

(3) $$m_t = \omega r_t + (1-\omega)d_t \qquad 0<\omega<1$$

(4) $$(M_t - M_{t-1}) + (B_t - B_{t-1}) - s_t(R_t - R_{t-1}) = \Delta_t + i_{t-1}B_{t-1}$$

where s_t is the spot exchange rate of pesos in terms of foreign currency, $m_t = \log(M_t)$ denotes the money supply, $r_t = \log(R_t)$ international reserves (denominated in foreign currency), and $d_t = \log(D_t)$ domestic credit. B_t denotes the stock of government bonds, and i_t denotes the interest rate. The domestic and foreign price levels are given by p_t and p_t^* respectively. $E_t(.)$ denotes the expectations operator given information at time t. Δ_t denotes the primary deficit (net of interest charges). It is assumed that the error terms e_{1t}, e_{2t} are i.i.d. (independently and identically distributed) with zero mean.

Equation (1) is a Cagan type of money demand function used for studying hyperinflationary periods. Alternatively, the interest rate, i_t, could have been specified in place of the inflationary expectations term, $(E_t p_{t+1} - p_t)$. However, in view of Table 1, inflationary expectations should play a significant role. Moreover, in models specifying an interest rate instead, an interest parity (U.I.P.) condition is also modeled, $i_t - i_t^* = (E_t s_{t+1} - s_t)$, which unfortunately holds only if all speculators are risk-neutral, an assumption which may not hold during periods of high inflation and risks of devaluation (the 'Peso' Problem). Equation (2) allows for deviations from PPP. Equation (3) is a money supply definition which states that the monetary base is a combination of international reserves and domestic credit. When the country goes off a fixed exchange rate standard, it is usually assumed that $\omega = 0$; that is, the monetary base is backed entirely by domestic credit. Alternatively it may be assumed that $r_t = r_{min}$ when the regime ends, where r_{min} is a threshold level below which the policy authorities give up defending a parity rule. Finally equation (4) is the flow government budget constraint.

The constraint can be solved forward in time so that the impact of current and past deficits on future government financing needs can be evaluated.

Appendix 1 solves (4) forward in time and reaches the conclusion that domestic credit growth is linked to the growth in deficits. This specification departs form previous empirical work in which domestic credit creation is treated exogenously. Here, domestic credit creation is postulated to be some function of government deficits:

(5a) $d_t = \psi_0 + \psi_1 def_t + u_{1t}$.

where u_{1t}. is an iid error and zero mean.

The following equations describe the processes of the state variables. For now an AR(1) specification is assumed. Later in Section V these specifications are corrected for first-order autocorrelation.

(5b) $def_t = \gamma_0 + \gamma_1 def_{t-1} + u_{2t}$

(5c) $p_t^* = \xi_0 + \xi_1 p_{t-1}^* + u_{3t}$

where u_{2t} and u_{3t} are also iid with zero mean, and def_t is the log of the deficit, including interest payments, at time t[5].

Solutions

I first derive the shadow floating exchange rate $\tilde{s}$ in the absence of a crawling peg so that its path can be estimated for periods in which a crawling peg regime is in place. Substituting equations (2), (3), and (5a) into (1) and rearranging gives:

$$(1 + \alpha_1)\, \tilde{s}_t = \alpha_1 E_t\, \tilde{s}_{t+1} + \omega r_{min} + (1 - \omega)\psi_0 + (1 - \omega)\psi_1 def_t -$$
$$(1 + (\alpha_1 - \alpha_1\xi_1))p_t^* - (\alpha_1 - \alpha_1\xi_0) - (1 - \alpha_1)\, e_{2t} - e_{1t} + (1 - \omega)\, u_{1t}$$

where the reserve component of the monetary base is assumed to stay constant at the minimum threshold level, r_{min}.

Let $h_t = \omega r_{min} + (1-\omega)\psi_0 - (1 + (\alpha_1 - \alpha_1\xi_1))p_t^* - (\alpha_1 - \alpha_1\xi_0) - (1-\alpha_1)e_{2t} - e_{1t} + (1-\omega)u_{1t}$

Thus,

$$(6) \qquad \tilde{s}_t = \frac{1}{(1+\alpha_1)}\left[h_t + (1-\omega)\psi_1 def_t\right] + \frac{\alpha_1}{(1+\alpha_1)} E_t \tilde{s}_{t+1}$$

for which the convergent forward looking solution is:

(7) $$\tilde{s}_t = \frac{1}{1+\alpha_1}\sum_{i=0}^{\infty}\left(\frac{\alpha_1}{1+\alpha_1}\right)^i E_t h_{t+i}\left(\frac{(1-\omega)\psi_1}{1+\alpha_1}\right)\sum_{i=0}^{\infty}\left(\frac{\alpha_1}{1+\alpha_1}\right)^i E_t def_{t+i}$$

that is, the shadow exchange rate depends on expected discounted future market fundamentals.

To obtain more specific results, assume also that the other remaining fundamentals follow an AR(1) process:

(5d) $$h_{t+i+1} = f_0 + f_1 h_{t+i} + e_{3t+i+1}$$

where again e_{3t+i+1} is assumed to be iid with zero mean. The empirical results of the AR(1) processes are discussed in Section V.

Substituting (5b, c, d) into (7) gives

(8a) $$\tilde{s}_t = \alpha_1\left(\frac{1}{u_h}f_0 + \frac{1}{u_d}\gamma_0\right) + \frac{1}{u_d}def_t + \frac{1}{u_h}\left[k_1 - k_2 p_t^* + k_e\right] + \text{error}$$

where

$$k_1 = -(\alpha_0 - \alpha_1\xi_0) + \omega r_{min} + (1-\omega)\psi_0$$
$$k_2 = (1 + \alpha_1(1-\xi_1))$$
$$k_3 = (1-\omega)\psi_1$$
$$k_e = (1-\omega)u_{1t} - e_{1t} - (1+\alpha_1)e_{2t}$$
$$u_d = (1 + \alpha_1(1-\gamma_1)),\quad u_h = (1 + \alpha_1(1-f_1)).$$

Another way to write (8a) more amenable for econometric purposes is:

(8b) $$\tilde{s}_t = \beta_0 + \beta_1 def_t + \beta_2 p_t^* + \text{error},$$

where

$$\beta_0 = \alpha_1\left(\frac{1}{u_h}f_0 + \frac{1}{u_d}\gamma_0\right) + \frac{1}{u_h}k_1$$
$$\beta_1 = \frac{k_3}{u_d},\quad \beta_2 = -\frac{k_2}{u_h},\quad \text{error} = k_e$$

and it is expected that $\beta_1 > 0$ and $\beta_2 < 0$.[6] The reasons for these signs are that (i) deficit growth works to reduce money demand and lead to a depreciating currency, while (ii) increases in foreign prices work to favor home money demand and lead to a strengthening of the home currency.

Policy Rule

Under a pre-announced crawling peg system, the policy authorities announce a series of devaluation rates δ_t, δ_{t+1}, δ_{t+2}, ... in advance. In Argentina, the idea conceived of in December 1978 was to begin the crawl at roughly 5% in January 1979 and to reach zero per cent by March 1981. Therefore the exchange rate at time t+1 is, if there is no devaluation, $s_{t+1} = s_t(1 + \delta_{t+1})$. Otherwise if a speculative attack and devaluation occur, the shadow exchange rate, $\bar{s}_{t+1}$, emerges. More compactly:

$$
s_{t+1} = \begin{cases} \bar{s}_{t+1} & \text{if } \bar{s}_{t+1} > s_t(1+\delta_{t+1}) \\ s_t(1+\delta_{t+1}) & \text{otherwise} \end{cases} \tag{9}
$$

III. Data Set and Sample Period

Four important variables in the model are domestic credit, government deficits, the foreign price level, and spot exchange rate. All data are monthly and are from the IMF's International Financial Tapes. It would have been ideal to have included real output in the money demand function, but the data sources relied on did not provide monthly measures of GDP, GNP, or of a reasonable proxy like the index of industrial output. As a proxy for foreign prices, the U.S. Consumer Price Index is used.

Specifically, d_t is the logarithm of the domestic credit of the Central Bank at the end of the month in billions of pesos. def_t is the logarithm of the public sector financial deficit, defined as the discrepancy between revenues and expenditures, including interest payments on debt, on a cash-flow basis in billions of pesos. s_t is the logarithm of the spot exchange rate at the end of the month in pesos per dollar. p_t^* is the logarithm of the U.S. consumer price index, with 1980 = 100.

In Charts 1-3 are plots among the exchange rate, domestic credit, and public sector deficits. All series have been scaled so as to be more visually comparable in the plots. The co-movement between domestic credit and the exchange rate is very close, as is (but to a lesser degree) the co-movement between domestic credit and deficits. Note the sharp increase in the deficits at the end of 1980. The actual collapse date is June 1981. Severe speculative attacks have occurred in February, April, and June of 1981. The government attempted to salvage the program in May 1981 by carrying out a previously announced rate of crawl for that month but failed to prevent the attack of June 1981.

The remainder of this section will focus on the choice of sample period - mid 1977 to mid 1982. Enough uncensored sample observations are required to estimate the shadow exchange rate. One difficulty with the Argentinean case is that governments have frequently been controlling exchange rates, instituting two-tier rates or fixing exchange rates on various occasions. In this regard, the World Currency Yearbook is helpful for selecting periods of floating, or controlled floating. The crawling peg system was in place between January 1979 to June 1981. Between July 1977 to December 1978, and between July 1981 to June 1982, the free market peso was under controlled floating. Before July 1977 and after June 1982, different kinds of exchange rate regimes were instituted. Thus I estimate the shadow exchange rate only on the basis of observations from July 1977 to December 1978 and from July 1981 to June 1982.

IV. Estimation Framework, Methodology, and Results

Framework

The estimation technique adopted is that of censored (Tobit) regression. To that end, (9) is rewritten as follows:

$$(10) \qquad y_{t+1} = s_{t+1} - s_t(1+\delta_{t+1}) = \begin{cases} \tilde{s}_{t+1} > s_t(1+\delta_{t+1}) & \text{if RHS} > 0 \\ 0 & \text{otherwise} \end{cases}$$

where $\tilde{s}_{t+1} = \beta_0 + \beta_1 def_{t+1} + \beta_2 p_{t+1}^* + \text{error}$, and δ_{t+1} is the pre-announced rate of crawl; under controlled floating, $\delta_{t+1} = 0$. During the crawling peg era, all such δ_{t+1} were announced in advance.

A few remarks are in order. First, the constant term β_0 contains r_{min}, which is assumed to be fixed. Others such as Blanco-Garber (1986) and Cumby-van Wijnbergen (1987) estimate r_{min}, though they also treat it as fixed. In the estimated model presented here the r_{min} is absorbed in the constant term and cannot be isolated. Future work should try to identify the level.[7]

Secondly the def_t, p_t^* series do seem to be well explained by AR(1) processes, as indicated in Table 2a. However, the Durbin-Watson statistics indicate some need for correction,[8] namely:

$$(5a)' \qquad d_t - \rho_1 d_{t-1} = \psi_0(1-\rho_1) + \psi_1(def_t - \rho_1 def_{t-1}) + u_{1t}'$$

$$(5b)' \qquad def_t - \rho_2 def_{t-1} = \gamma_0(1-\rho_2) + \gamma_1(def_{t-1} - \rho_2 def_{t-2}) + u_{2t}'$$

$$(5c)' \qquad p_t^* - \rho_3 p_{t-1}^* = \xi_0(1-\rho_3) + \xi_1(p_{t-1}^* - \rho_3 p_{t-2}^*) + u_{3t}'$$

where ρ_1, ρ_2, and ρ_3 are the first-order serial correlation coefficients. The estimated results are presented in Table 2b. It is found that d_t follows an AR(1) process very well with no autocorrelation (asymptotically):

(5e) $\quad d_t - \upsilon_0 + \upsilon_1 d_{t-1} + u_{4t}$.

Resubstituting (5a)'-(5c)', (5d), and (5e) into (7) gives another version of (8a) to be estimated, namely,

(8b)' $\quad \bar{s}_t = \beta_0 + \beta_1 def_t + \beta_2 def_{t-1} + \beta_3 p_t{}^* + error.$[9]

Methodology

Let X=[I def def_{-1} p*] be a Tx4 matrix where I is a column vector of ones, and let $\beta' = [\beta_0 \;\; \beta_1 \;\; \beta_2 \;\; \beta_3]$ be a 1x4 vector of parameters. The sample period contains 60 observations of which a certain number, N1 (=30), are censored observations, namely those between January 1979 and June 1981. N2 (=30) then is the number of observations for which the shadow exchange rate can be observed (and N1 + N2 =60).

The first part of the estimation is the Heckman-Lee Two-Stage procedure, for which the estimates are consistent but inefficient, rendering tests of significance invalid. The second part consists of using these consistent estimates as the starting values for a maximum likelihood estimation procedure.

The errors in (8b) are assumed to be normally distributed. Consequently the first stage of Heckman-Lee involves a probit estimation:

$$(11) \qquad \max_{\beta} \log L = \sum_{t=1}^{60} d_t \log\Phi \frac{(\beta' X - c)}{\sigma} + \sum_{t=1}^{60} (1-d_t)\log\left[1-\Phi\frac{(\beta' X - c)}{\sigma}\right]$$

where d_t=1 if $t \in$ N2
=0 if $t \in$ N1

t=1,...60

(that is, d_t=1 if y_t>0 and d_t=0 if y_t=0), and $\Phi(.)$ is the standard normal cumulative distribution function, and c is a vector of $s_t(1+\delta_{t+1})$ for t=1,...,60. Note that β, σ cannot be estimated separately; the standard procedure here is to normalize σ to unity. Given an estimate of $\hat{\beta}$, one can estimate $\hat{\Phi}(.)$ and the probability density function, $\hat{\phi}(.)$. The second stage of the Heckman-Lee involves OLS on:

(12) $\quad E(y_t) = \hat{\Phi}(.)_t(\beta' x_t - c) + \sigma\hat{\phi}(.)_t$ for all 60 observations.

Finally, estimates of $\hat{\beta}$, $\hat{\sigma}$ from (12) are used as initial starting values for the Tobit MLE:

$$(13) \qquad \max_{\beta,\sigma} \log L = \sum_{t=1}^{60} d_t \log\left(\frac{1}{\sigma}\phi\left(\frac{y_t - x_t\beta - c}{\sigma}\right)\right) + \sum_{t=1}^{60}(1-d_t)\log\Phi\left(\frac{c - x_t\beta}{\sigma}\right)$$

where d_t is as defined before. The first sum on the right-hand side of equation (13) refers to observations for which the shadow floating rate coincides with the actual exchange rate and the second sum refers to observations during the censored (crawling-peg) regime.

Results

The probit regression results are presented in Table 3. All signs are as expected. The $\hat{\Phi}(.)$, $\hat{\phi}(.)$ are evaluated using these estimates. The results of the last stage of Heckman-Lee are presented in Table 4. The signs are all as expected, which are reproduced here for convenience:

$\hat{\beta}_0 = 52.5 \quad \hat{\beta}_1 = 0.65 \quad \hat{\beta}_2 = 1.45 \quad \hat{\beta}_3 = -13.13 \quad \hat{\sigma} = 1.81$

The t-statistics are strong, though incorrect because of the heteroskedasticity inherent in the Heckman-Lee procedure.

In Table 5 are the main results of MLE using the above β's as starting values. They are reproduced here for convenience:

$\hat{\beta}_0 = 40.2 \quad \hat{\beta}_1 = 0.672 \quad \hat{\beta}_2 = 1.08 \quad \hat{\beta}_3 = -9.8 \quad \hat{\sigma} = 0.69$

The signs are correct and the t-statistics are decisively strong. Compared to the Heckman-Lee estimates, they are smaller in absolute magnitude, with the exception of β_1 which has only imperceptibly changed in value.

Section VII uses these results to conduct some within-sample (or ex post) experiments, such as computing one-step ahead devaluation/attack probabilities. Before proceeding there, the next section reports the results of some tests on the model.

V. Tests of the Model

Wald Test

The objective here is to test the restriction that all coefficients except the constant term should be zero. The test statistic is compared to a chi-square distribution with 3 degrees of freedom. The result is that the null hypothesis that $\beta_1 = \beta_2 = \beta_3 = 0$ is rejected at the 5% level of significance.

Misspecification Test

The Nelson (1981) version of the Hausman Misspecification Test is used to determine whether the model is robust to the assumption of a normally distributed cdf (and pdf). The test essentially involves comparing the maximum-likelihood estimates against the method-of-moments estimates. The method-of-moments gives consistent estimates whether or not the underlying distribution is normal, while the ML estimates are consistent only under normality. Thus under the null hypothesis of 'normality', the discrepancy between the two estimates should be small, while large under the alternative hypothesis. The test statistic is compared to a chi-square distribution with k=4 degrees of freedom, where k is the dimension of the parameter vector. I could not reject the null hypothesis that the distribution is normal at the 10% level of significance.

Serial Correlation Test

This section applies a test for first-order serial correlation developed by Lee (1984) to equation (8b), the reduced-form equation for the shadow exchange rate. Lee's test can be regarded as a generalization of the Durbin-Watson test. Since the test is originally formulated for a bivariate (or two equation) system, the test must be modified somewhat for the single equation case. Appendix 2 outlines the procedure in more detail. As an overview, the test-statistic is basically the square of the sum of functions (defined in Appendix 2) of autocorrelated disturbances divided by the sum of the square of those functions of autocorrelated disturbances. The test-statistic is asympototically chi-square distributed with (in this instance) one degree of freedom.

The results are as follows. The null hypotheses of the absence of first-order serial correlation is rejected at the 5% level of significance but is not rejected at the 1% level of significance. In other trials, when further lagged values of deficits are added (for example, def_{t-2}, def_{t-3}) to equation (8b), the serial correlation problem disappears at the 5% level of significance. Their inclusion in the reduced-form equation (8b) would be justified theoretically if changes are made to the specification of movements in the underlying fundamentals (like deficits, prices, and domestic credit creation) in equations (5a)-(5c); for example, an AR(2) process could be postulated for deficit growth. Nevertheless this paper has proceeded with the theoretical assumptions and specifications presented in Section II, as the simple (first-order or one-lagged) structure sufficed to produce some reasonable results. Robinson (1982) has noted that in the context of Tobit models, serial correlation difficulties pose problems for the efficiency of estimates (and significance tests based thereon) but not for the consistency of the ML estimates.

VI. Experiments

The following within-sample predictions are reported: (i) the one-step ahead devaluation probabilities; (ii) the exchange rate conditional on a devaluation; (iii) the unconditional exchange rate. The results are presented in Tables 6 and 7, and in Charts 4, 5, and 6.

The probability of attack is given by the cumulative distribution function, $Prob(y_t>0)=\hat{\Phi}_t((X_t\hat{\beta}-c)/\hat{\sigma})$, given information at t-1. The conditional and unconditional exchange rate equations are given respectively by:

$$E(\bar{s}_t|y_t>0)=\hat{\beta}x_t+\hat{\sigma}\left(\hat{\phi}_t(.)/\hat{\Phi}_t(.)\right)$$

and

$$E(\bar{s}_t)=\hat{\Phi}_t(.)\hat{\beta}_t(x_t-c)+\hat{\sigma}\hat{\phi}_t(.)+c.$$

Conditional exchange rates are what exchange rates would be if attacks were to occur, and according to Table 7 and Chart 5, the conditional rates overpredict the actual rates (as would be the case if a devaluation were expected in each period). The unconditional exchange rates have the interpretation of being the model's own predictions of the actual exchange rate series. The predictions are rather good, although there is a tendency for overprediction in the post-collapse period.

The probability of attack series indicate that there has always been some positive probability of a devaluation looming in the background. The probabilities are relatively low during the initial phases of the crawling peg. They rise, as expected, in the latter phases. During the period in which the crawling peg was not in place, the relative lack of exchange rate predictability enables the probabilities to be higher on average. Note, however, that the probabilities reach a peak in January 1981, six months earlier than the actual date of collapse. This is influenced by the fact that the government deficit itself reaches a peak in December 1980 (recall Charts 2, 3). Thus according to the model, the fundamentals predict an earlier collapse. In actuality, a series of attacks occurred in February, April, and June of 1981, involving devaluations of 10, 31, 30 per cent respectively. The source of the conflict may be due to a weakness with using "one-step" ahead probability measures, since the information available at any time is used only to compute the probability of an event one period later. A better measure would be a k-step ahead probability of devaluation ($k > 1$). Another weakness with the model is that it leaves out information as to why and how the Argentinean government tried to cling on to the program, through political efforts in March and May of 1981, despite market pressure.

VII. Conclusion

In summary the results support the view that a deficit growth path that is inconsistent with monetary and exchange rate stabilization leads to speculative attacks and to a collapse of an exchange rate regime. That is, rapid deficit growth in the presence of 'tight' money eventually implies future money creation in order that the public debt can be financed (or monetized). When inflationary taxes are anticipated (owing to an expected increase in future monetary expansion), private agents will reduce their money demand through the Cagan price expectations term in equation (1), and higher current prices will result to clear the money market. The increased current inflation will weaken the domestic currency and make it profitable to launch buying attacks against central bank reserves.

This paper employed censored regression techniques to estimate a shadow exchange rate for a crawling peg regime. The shadow rate signals whether speculative attacks against a crawling peg regime can be profitable. Overall the results support the view that public sector deficits drive movements in the shadow exchange rate, indicating that deficit growth inconsistent with the monetary and exchange rate policies in place are ultimately behind the breakdown of a crawling peg regime.

I will conclude with some suggestions for further research. First it would be desirable to extend the empirical specification of the model. For instance, a measure of the transactions demand for money, such as real output, should be included, and the minimum threshold level, r_{min}, should be identified explicitly.

A related area to investigate is the literature on target zone models of exchange rate dynamics. A two-limit Tobit framework may be used to model the upper and lower thresholds of a target zone. Both devaluations and revaluation can be considered and would be useful for studying exchange rate misalignments in the EMS where unusual movements in both strong and weak currencies can seriously affect exchange rate management.

Another modeling strategy would be to use a 'duration' framework, if enough events in the sample permit. The intuitive idea here is to study the survival rates of exchange rate regimes. Along this line a panel data study could be set up as in Hajivassiliou (1988). One purpose would be to see whether there are country-specific reasons for speculative attacks or common ones, such as a weakening demand for Latin American exports by the United States or other industrialized countries. Another purpose would be to integrate the factors that ignite debt crises, capital flight, and currency substitution, with those that incite speculative attacks. Intuition suggests that there ought to be common origins for the various factors that expose countries to serious financial and other risks.

Appendix 1: The Intertemporal Government Budget Constraint

Recall equation (4):

(A1) $$(M_t - M_{t-1}) + (B_t - B_{t-1}) - s_t(R_t - R_{t-1}) = \Delta_t + i_{t-1}B_{t-1}$$

Let R_t be the value of reserves denominated in domestic currency and in terms of book-value - i.e. $(\tilde{R}_t - \tilde{R}_{t-1}) = s_0 (R_t - R_{t-1})$ - so as to avoid having to keep track of changes in the exchange rate.

Now,

(A2)
$$(M_t - M_{t-1}) + (B_t - B_{t-1}) - (\tilde{R}_t - \tilde{R}_{t-1}) = \Delta_t + i_{t-1}B_{t-1}$$
$$(M_{t+1} - M_t) + (B_{t+1} - B_t) - (\tilde{R}_{t+1} - \tilde{R}_t) = \Delta_{t+1} + i_t B_t$$
$$\vdots$$

and so forth.

Let $Z_t = \Delta_t + i_{t-1}B_{t-1} - (B_t - B_{t-1}) + (\tilde{R}_t - \tilde{R}_{t-1})$ be the "monetized" part of the financial deficit. Hence, Z_t - $(M_t - M_{t-1})$.

As mentioned in the text, when exchange rates are not fixed, M_t is backed by domestic credit, D_t. Thus:

(A3)
$$Z_t = (D_t - D_{t-1})$$
$$Z_{t+1} = (D_{t+1} - D_t)$$
$$\vdots$$

Solving recursively,

(A4) $D_T = D_t + \sum_{i=t}^{T} Z_i$ for $t<T$, where T is some date in the future.

Equation (A4) indicates that at time t, agents will see that the stock of domestic credit at time T will be affected by the sum of "deficits" incurred between t and T. Current deficits must be matched by future surpluses, and vice versa, if there is to be no change in inflationary implications (ie. for given D_T-D_t); for example, increased indebtedness today that defers real taxes or money creation today must eventually be paid by real taxes or money creation in the future.

In order to adjust (A4) for inflation, (A3) is rewritten as:

(A3)' $\frac{D_t}{P_t} - \frac{D_{t-1}}{P_t} = \frac{Z_t}{P_t}$

where P_t is the price level. This gives

$$d_t = \left(\frac{1}{1+\pi_t}\right) d_{t-1} + z_t$$

where $\pi_t = \frac{P_t}{P_{t-1}} - 1$ is the inflation rate, and $d_t = \frac{D_t}{P_t}$ and $z_t = \frac{Z_t}{P_t}$.

Solving the above recursively, gives:

(A5) $$\bar{d}_T = \prod_{j=t+1}^{T}\left(\frac{1}{1+\pi_t}\right)\bar{d}_t + \sum_{i=t+1}^{T}\prod_{k=1}^{T-i}\left(\frac{1}{1+\pi_{i+k}}\right) z_i$$

i.e. the intertemporal budget constraint in real terms. Thus, domestic credit creation between (t, T) depends on the entire future path of government deficits. The main text specifies how Z_i, or z_i, evolves over time.

Appendix 2: Lee's Test for Serial Correlation

Assume the model is:
$$y_{1t} = x_{1t}.\beta_1 + u_{1t}$$
$$y_{2t} = x_{2t}.\beta_2 + u_{2t}.$$

$u_{1t} = \rho_1.u_{1t-1} + e_{1t}$, $u_{2t} = \rho_2.u_{2t-1} + e_{2t}$, and

Suppose $\sum = \begin{bmatrix} \sigma_1^2 & \sigma_{12} \\ \sigma_{12} & \sigma_2^2 \end{bmatrix}$

Under the null hypothesis of no first-order serial correlation, $\rho 1 = \rho 2 = 0$.

Let
$$c_{1t} = \left(u_{1t}^* - \left(\sigma_{12} / \sigma_2^2\right).u_{2t}^*\right).u_{1t-1}^* \text{ and}$$
$$c_{2t} = \left(u_{2t}^* - \left(\sigma_{12} / \sigma_1^2\right).u_{1t}^*\right).u_{2t-1}^*,$$

where the asterisks denote the estimated sample residuals of u_{1t} and u_{2t}.

Now let $c_t = (c_{1t}, c_{2t})'$ and construct the scoring statistic

$$\Gamma = \left(\sum_{t=2}^{T} c_t'\right)\left(\sum_{t=2}^{T} c_t\, c_t'\right) - 1 . \left(\sum_{t=2}^{T} c_t\right)$$

where under regularity conditions, this test-statistic is asymptotically distributed as chi-square and 2 degrees of freedom. Thus if this Γ exceeds $\chi^2(2)$ at some specified level of significance (say 5%), the null hypothesis is rejected.

Now if there is only one equation in the system, say $y_{1t} = x_{1t}.\beta_1 + u_{1t}$, then set $u_{2t} = 0$, and consequently σ_{12}=0, so that c_t=c_{1t} only. The rest of the test procedure can then be followed in an analogous way - with Γ being distributed as chi-square with one degree of freedom.

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Chart 1

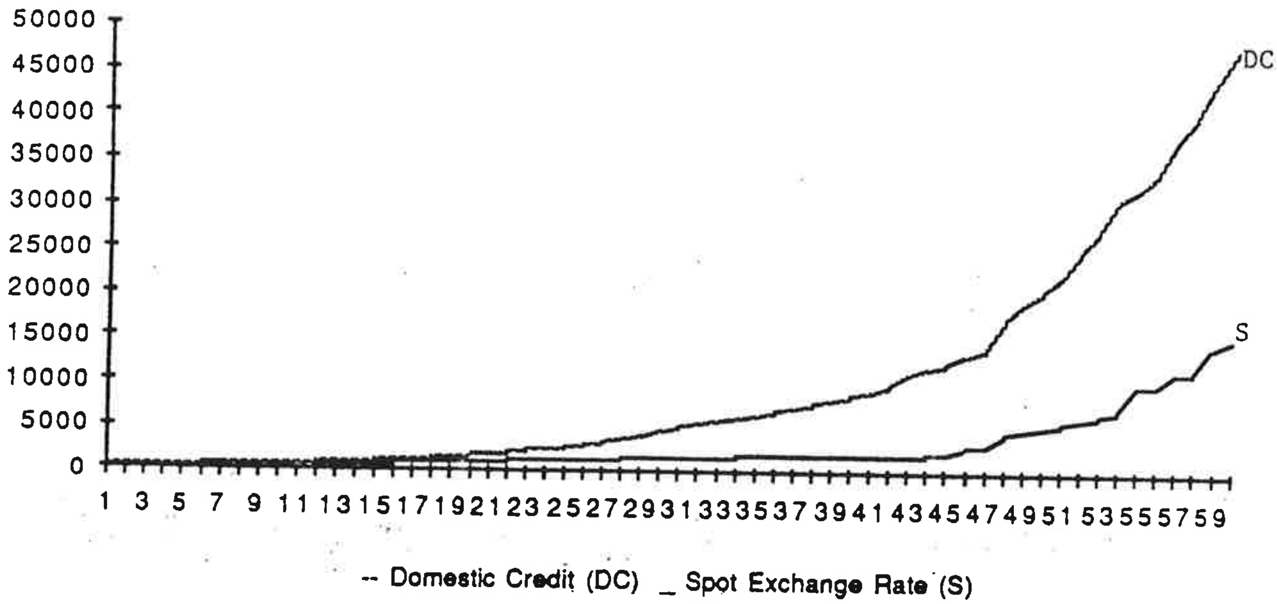
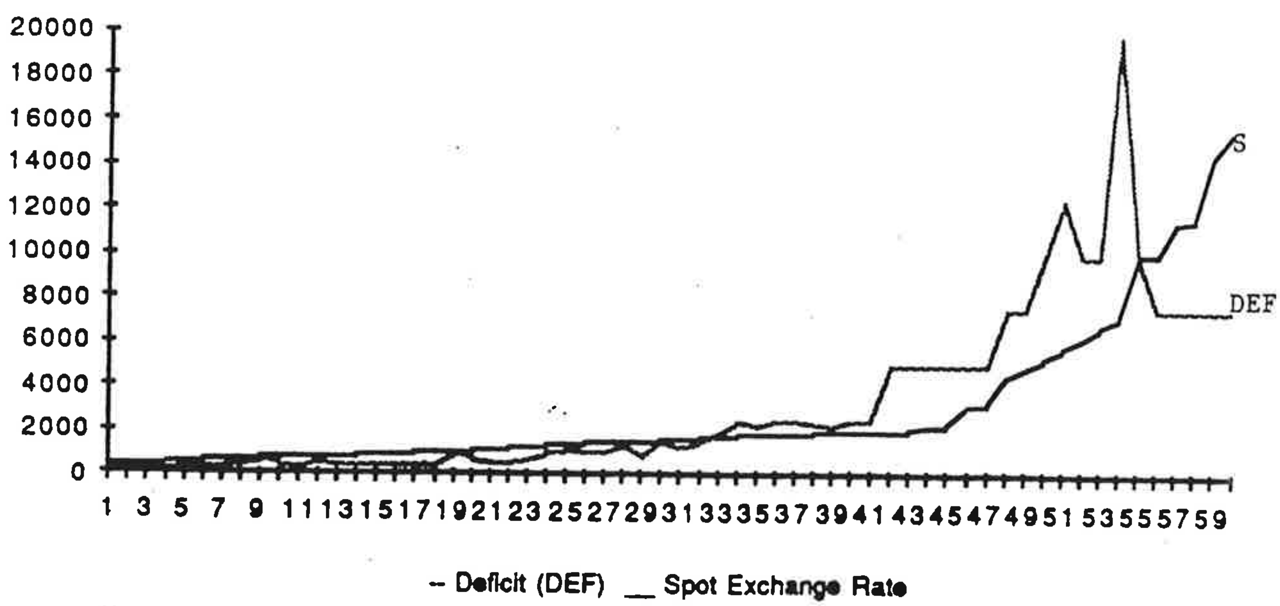
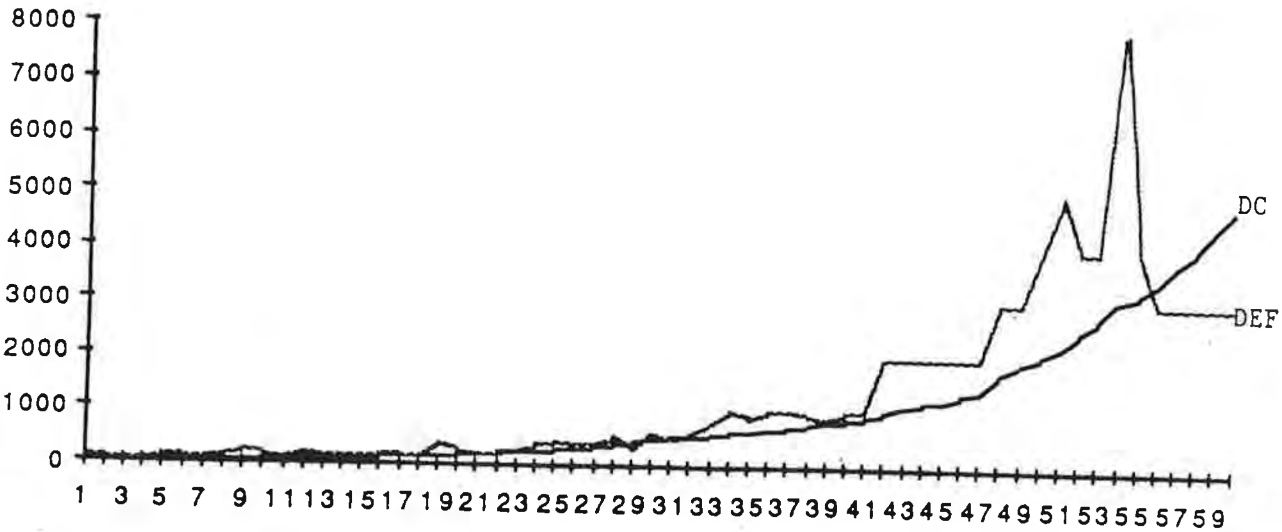


Chart 2



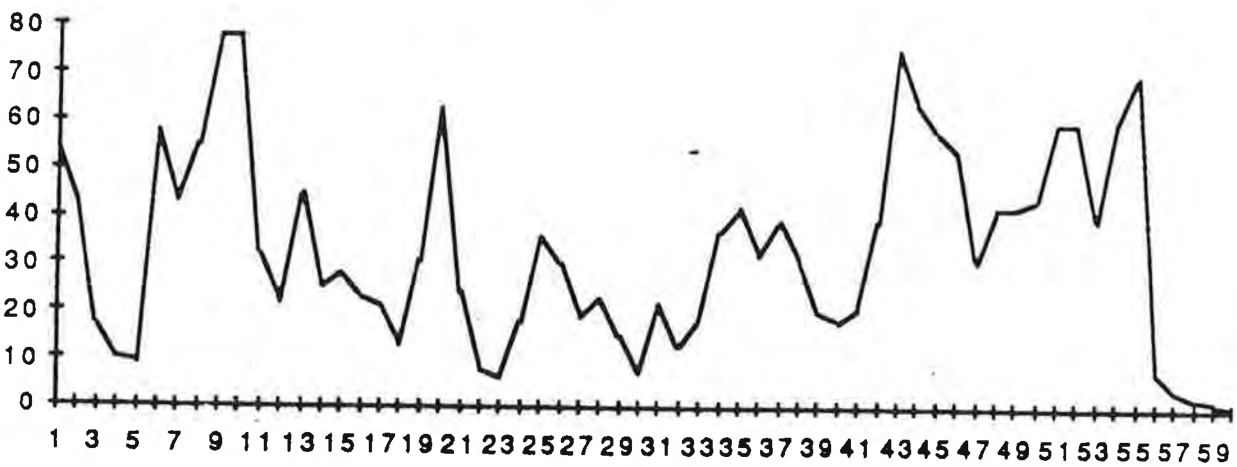
Notes: Observation 1 corresponds to July 1977, ... , Observation 30 corresponds to December 1979, ... , Observation 60 corresponds to June 1982. Observations 19 to 48 correspond to the crawling peg regime: January 1979 to June 1981.

Chart 3



-- Deficit (DEF) __ Domestic Credit (DC)

Chart 4

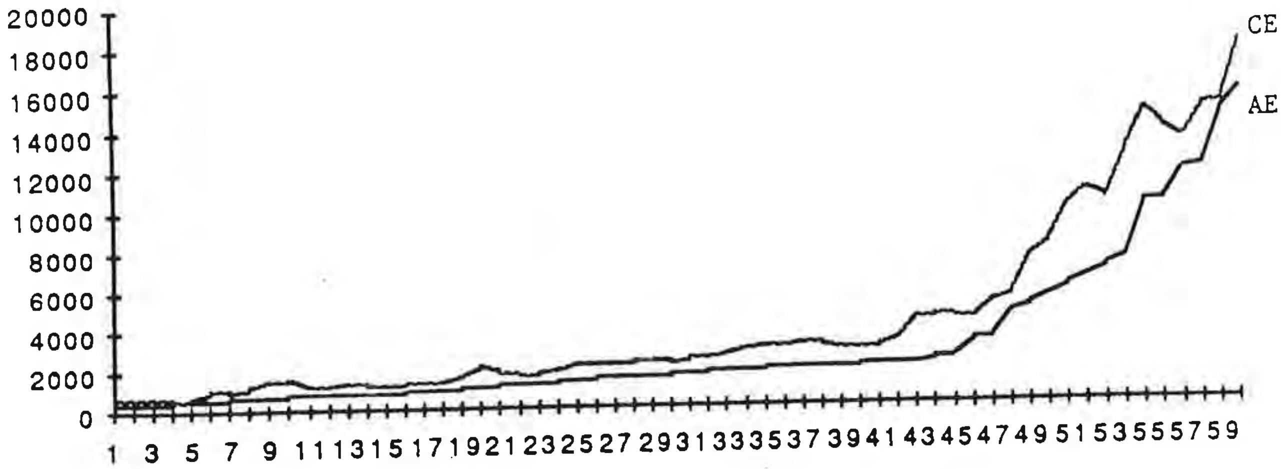


Probabilities of Attack.

(Observation 43 corresponds to January 1981)

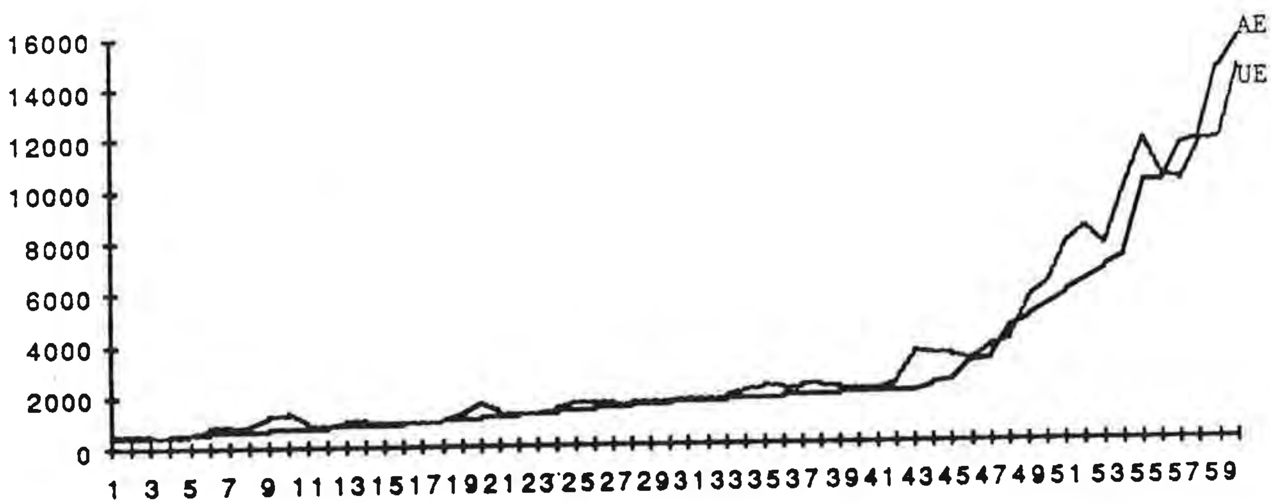
Notes: Observation 1 corresponds to July 1977, ... , Observation 30 corresponds to December 1979, ... , Observation 60 corresponds to June 1982. Observations 19 to 48 correspond to the crawling peg regime: January 1979 to June 1981.

Chart 5



-- Conditional Exchange Rate (CE)
__ Actual Exchange Rate (AE)

Chart 6



-- Unconditional Exchange Rate (UE)
__ Actual Exchange Rate (AE)

Notes: Observation 1 corresponds to July 1977, ... , Observation 30 corresponds to December 1979, ... , Observation 60 corresponds to June 1982. Observations 19 to 48 correspond to the crawling peg regime: January 1979 to June 1981.

Table 1

Selected Annual Inflation Rates

Year	U.S.A.	Argentina
1972	3.3	58.42
1973	6.23	61.2
1974	10.97	23.5
1975	9.14	182.3
1976	5.77	443.2
1977	6.51	176.1
1978	7.6	175.5
1979	11.31	159.5
1980	13.47	100.8
1981	10.35	104.5
1982	6.16	164.8
1983	3.22	343.8

Calculations based on the Consumer Price Index reported in the IMF's International Financial Statistics, various issues.

Table 2a

Regression Results for Equations 5(a)-5(d)

T-statistics are in parentheses, and degrees of freedom are 58.

(5a) $d_t = 4.02 + 1.0385 def_t$ R-squared 0.9344
(17.04) (28.75) Durbin-Watson 1.4944

(5b) $def_t = 0.324 + 0.9584 def_{t-1}$ R-squared 0.93
(1.44) (27.57) Durbin-Watson 2.74

(5c) $p_t^* = 0.0086 + 0.999 p_{t-1}^*$ R-squared 0.9995
(0.642) (339.5) Durbin-Watson 0.71

(5d) $d_t = 0.125 + 0.9962 d_{t-1}$ R-squared 0.9996
(4.673) (397.3) Durbin-Watson 1.913

Table 2b

Correction for First-Order Serially Correlated Errors

T-statistic are in parentheses; degrees of freedom are 58; ρ indicates the first-order transformation coefficient.

$$(5a)' \quad (d_t = \hat{\rho} d_{t-1}) = 2.645 + 0.951(def_t - \hat{\rho} def_{t-1})$$
$$(13.5) \quad (18.4)$$

$\hat{\rho} = 0.4$

R - squared 0.8543

Durbin - Watson 1.8634

$$(5b)' \quad (def_t - \hat{\rho} def_{t-1}) = 0.284 + 0.977(def_{t-1} - \hat{\rho} def_{t-2})$$
$$(1.36) \quad (41.41)$$

$\hat{\rho} = -0.37$

R − squared 0.9673

Durbin - Watson 2.174

$$(5c)' \quad (p_t{*} - \hat{\rho} p_{t-1}{*}) = 0.003 + 0.999(p_{t-1}{*} - \hat{\rho} p_{t-2}{*})$$
$$(0.281) \quad (158.1)$$

$\hat{\rho} = 0.65$

R - squared 0.9977

Durbin - Watson 2.108

Note: For the given degrees of freedom, the 5% significance points for the Durbin-Watson statistic are d_L=1.55, d_U-1.62 and (4-d_L)=2.45, (4-d_U)=2.38.

Table 3

Heckman-Lee Methodology Stage 1: Probit Results

T-statistics are in parentheses.

Constant	$\beta_0 = 59.3$ (2.185)
Def_t	$\beta_1 = 0.7134$ (1.1782)
Def_{t-1}	$\beta_2 = 1.494$ (2.345)
p_t^*	$\beta_3 = -14.487$ (-2.044)

Table 4

Heckman-Lee Methodology Stage 2: OLS on all yt

T-statistics are in parentheses. Note that the standard errors in the second stage are incorrect. See Hajivassiliou (1988).

Constant	$\beta_0 = 52.5$ (9.93)
Def_t	$\beta_1 = 0.65$ (8.31)
Def_{t-1}	$\beta_2 = 1.45$ (12.41)
p_t^*	$\beta_3 = -13.12$ (-9.32)
Standard Error	$\sigma = 1.81$ (10.91)

Table 5

Maximum Likelihood Estimates

T-statistics are in parentheses.

Constant	$\beta_0 = 40.2$ (41.43)
Def_t	$\beta_1 = 0.672$ (2.56)
Def_{t-1}	$\beta_2 = 1.08$ (4.13)
p_t^*	$\beta_3 = -9.8$ (-34.9)
Standard Error	$\sigma = 0.69$ (2.646)

Table 6. Probability of Attacks

Year	M	Probability of Attack	Year	M	Probability of Attack
1977	7	54	1981	1	75
1977	8	43	1981	2	64
1977	9	17	1981	3	58
1977	10	10	1981	4	54
1977	11	9	1981	5	31
1977	12	58	1981	6	42
1978	1	43	1981	7	42
1978	2	55	1981	8	44
1978	3	78	1981	9	60
1978	4	78	1981	10	60
1978	5	32	1981	11	40
1978	6	22	1981	12	60
1978	7	45	1982	1	70
1978	8	25	1982	2	8
1978	9	28	1982	3	4
1978	10	23	1982	4	2
1978	11	21	1982	5	1
1978	12	13	1982	6	0
1979	1	31			
1979	2	63			
1979	3	24			
1979	4	8			
1979	5	6			
1979	6	18			
1979	7	36			
1979	8	30			
1979	9	19			
1979	10	23			
1979	11	15			
1979	12	7			
1980	1	22			
1980	2	13			
1980	3	19			
1980	4	37			
1980	5	42			
1980	6	32			
1980	7	39			
1980	8	31			
1980	9	20			
1980	10	18			
1980	11	21			
1980	12	39			

Table 7. Actual, Conditional, and Unconditional Exchange Rates

Year	M	Actual Exchange Rate	Conditional Exchange Rate (given an attack)	Uncondtional Exchange Rate
1977	7	413.5	696.45	535.39
1977	8	437.5	686.77	514.40
1977	9	437.5	631.19	464.05
1977	10	513.5	601.85	450.34
1977	11	557.5	706.27	529.01
1977	12	597.5	1020.45	796.32
1978	1	641.5	991.28	742.48
1978	2	681.5	1144.82	880.07
1978	3	721	1525.38	1286.91
1978	4	761	1603.59	1352.89
1978	5	776.25	1190.35	877.43
1978	6	788.25	1156.32	849.80
1978	7	805.5	1326.10	999.25
1978	8	830.5	1218.04	895.16
1978	9	866.5	1272.83	935.42
1978	10	907.5	1294.66	953.37
1978	11	957.5	1342.11	986.14
1978	12	1003.5	1351.54	1001.15
1979	1	1055.5	1642.54	1210.27
1979	2	1104.5	2090.17	1646.32
1979	3	1156.5	1738.89	1276.78
1979	4	1209.5	1655.73	1241.13
1979	5	1263.5	1699.35	1285.88
1979	6	1316.5	1919.85	1411.77
1979	7	1369.5	2186.37	1618.52
1979	8	1421.5	2208.35	1618.83
1979	9	1472.5	2147.37	1579.72
1979	10	1522.5	2264.25	1664.03
1979	11	1517.5	2241.72	1654.91
1979	12	1618.5	2208.35	1654.25
1980	1	1663.5	2465.13	1815.65
1980	2	1706.5	2416.32	1782.25
1980	3	1747.5	2565.73	1881.21
1980	4	1785.5	2866.94	2125.18
1980	5	1821.5	3004.90	2243.56
1980	6	1854.5	2892.86	2139.30
1980	7	1884.5	3041.18	2274.10
1980	8	1910.5	2980.96	2191.90
1980	9	1933.5	2835.57	2088.36
1980	10	1952.5	2835.57	2086.98
1980	11	1972.5	2892.86	2136.02
1980	12	1992.5	3229.23	2405.02

Table 7. continued

		Actual Exchange Rate	Conditional Exchange Rate (given an attack)	Unconditional Exchange Rate
1981	1	2031	4315.64	3543.96
1981	2	2260	4359.01	3436.13
1981	3	2368	4315.64	3347.60
1981	4	3165	4230.18	3229.23
1981	5	3279	5115.34	3766.04
1981	6	4520	5431.66	4038.38
1981	7	4890	7405.66	5572.00
1981	8	5330	8103.08	6145.04
1981	9	5810	9897.13	7711.75
1981	10	6250	10721.43	8349.86
1981	11	6770	10198.54	7589.34
1981	12	7250	12581.72	9790.82
1982	1	10025	14617.87	11785.20
1982	2	10025	13766.59	10302.93
1982	3	11575	13226.80	10123.47
1982	4	11790	14764.78	11630.74
1982	5	14575	14913.17	11826.09
1982	6	15725	18033.74	14585.31

Endnotes

1 See for example Salant-Henderson (1978), Krugman (1979), Flood-Garber (1984), Grilli (1986), and Buiter (1987).

2 See Calvo (1986) for further details.

3 Other empirical studies of exchange regime collapses include Blanco-Garber (1986) on Mexico and Cumby-van Wijnbergen (1987) on Argentina. Both studies use different econometric methods from this paper and focus on monetary variables. This paper highlights the role of both fiscal and monetary variables.

4 Here the usual convention is followed in which s(t) is the ratio of pesos to foreign currency. Thus if s(t) is rising, pesos are depreciating in value, and vice versa.

5 The government financial balance throughout this period was in deficit so that there was no change in sign in the government balance which would affect the log values.

6 As it stands the model is underidentified since it is not possible to recover all the coefficients of the structural model. But for purposes of this paper the reduced form of equation (8b) should suffice. The role of the structural model has been to provide a theoretical basis for equation (8b).

7 If the methodology for finding r_{min} in Cumby-van Wijnbergen (1987) were applied here, the reduced form equation of $\bar{s}_{t+1}$ would be integrated numerically over all possible values of $r_t \varepsilon [r_L, r_U]$, where r_U is the current level of reserves and r_L is taken to be the gross foreign liabilities. In other words they are the supremum and infimum of reserves respectively.

8 There are difficulties with using the Durbin-Watson statistic in the presence of lagged endogenous variables, since the test statistic is biased towards 2, or towards acceptance. Ambiguities would thus result if the tests showed no serial correlation. In this paper, however, the tests indicated serial correlation. A more precise test is Durbin's large sample asymptotic test.

9 A lagged p_{t-1}^* could in principle enter (8b)', but its presence led to severe multicollinearity.