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**RECURRENT DEVALUATION AND SPECULATIVE ATTACKS ON
THE MEXICAN PESO**

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DOCUMENTO DE TRABAJO

Núm. XII - 1983

Recurrent Devaluation and Speculative Attacks on the Mexican Peso

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December, 1983

A B S T R A C T

In this paper, we generate an empirical method to predict the timing of speculative attacks on fixed exchange rate systems and the magnitude of the devaluation forced by an attack. Using Mexican data from 1973 to 1983, we produce time series estimates of the endogenous probability that the fixed exchange rate will collapse one period ahead. We also construct a time series of the expected next period exchange rate conditional on a devaluation. The probability series attains peak values for the observations prior to the 1976 and 1982 devaluations. In addition, the conditional expectations of the devalued exchange rates were close to the rates that actually materialized.

RESUMEN

En este trabajo presentamos un método empírico que permite predecir la calendarización de ataques especulativos contra un sistema de tasas de cambio fijas, así como la magnitud de la devaluación que provocará este ataque. Utilizando el caso de México entre 1973 y 1983, presentamos estimaciones de la probabilidad endógena del derrumbe de la tasa de cambio fija en el período subsiguiente. Asimismo construimos una serie de tiempo del valor de la tasa de cambio esperada en el período siguiente, condicional en que haya una devaluación. La serie de probabilidades tiene valores máximos para las observaciones anteriores a las devaluaciones de 1976 y 1982. Además, las estimaciones condicionales de la magnitud de la devaluación son muy semejantes a las que, de hecho, sucedieron.

In recent papers, several researchers have developed the concept of endogenously timed speculative attacks on asset price fixing regimes.¹ For different asset markets, this literature has demonstrated that the timing and magnitude of attacks can be determined by studying agents' rational speculative behavior. However, no effort has been made to implement these models empirically. In this paper, we generate an empirical method to predict the timing of speculative attacks on fixed exchange rate systems and the magnitude of the devaluation forced by an attack. To illustrate the applicability of the method, we analyze the Mexican exchange rate experience during the 1973-1982 period.

After almost twenty years of orthodox monetary policy and a stable exchange rate (1954-1972), the Banco de Mexico became a major source of public sector finance. Subsequently, Mexico has recently experienced a series of balance of payments crises.² Major exchange rate changes occurred in August, 1976, and in February and September of 1982. Also, the Banco de Mexico implemented a series of mini-devaluations during 1981. The Mexican government did not impose significant exchange controls until September, 1982.

Using the Mexican experience, we produce time series estimates of the endogenous probability that the fixed exchange rate will collapse one period ahead. We also construct a time series of the expected next period exchange rate conditional on a devaluation. The probability series attains peak values for the observations prior to the 1976 and 1982 devaluations. In addition, the conditional expectations of the devalued exchange rates were close to the rates that actually materialized.

1) The Devaluation Model

A money market continually in equilibrium constitutes the central component of our model:

$$m_t - p_t = \beta + \alpha y_t - \alpha i_t + w_t \quad (1)$$

where m_t , p_t and y_t are the logarithms of the money stock, the domestic price level and the aggregate output level, respectively. i_t is the domestic interest rate and w_t is some stochastic disturbance. We further assume that the price level and the interest rate are determined by

$$i_t = i_t^* + E e_{t+1} - e_t \quad (2)$$

$$p_t = p_t^* + e_t + u_t \quad (3)$$

where an asterisk signifies an exogenous foreign variable and e_t and u_t are the logarithms of the nominal and the real exchange rate, respectively. The operator E represents expectations conditional on information up to time t .

a. The Devaluation Policy

Equation (1) and movements of domestic credit determine the evolution of net foreign reserves. The central bank stops intervening in the foreign exchange market when reserves reach a critical level \bar{R} , measured in foreign currency units. If such an event materializes at time t , the central bank establishes a new fixed exchange rate \hat{e}_t using a time invariant policy rule. The government does not impose exchange controls.

As usual for a policy rule, \hat{e}_t will be a function of the model's stochastic state variables. While a given fixed exchange rate remains viable, \hat{e}_t remains in the background as a "shadow" exchange rate unobservable to the researcher. It attains visibility only at the moment of a devaluation. Of course, as the new fixed exchange rate which would be set after an attack, \hat{e}_t must itself always be a viable exchange rate. This requires that \hat{e}_t exceeds some minimum value which we will derive below.

The current fixed rate's viability depends on the relation between the fixed exchange rate and \hat{e}_t . Specifically, the condition that \hat{e}_t exceeds the current fixed exchange rate is equivalent to reserves' attaining their lower bound at time t , i.e. to a devaluation at time t . Sufficiency follows since agents can then profit from a speculative attack which forces a currency devaluation to \hat{e}_t . According to its policy, the central bank will sell international reserves until they reach the lower bound \bar{R} . At this point the bank will establish the new exchange rate \hat{e}_t , thereby providing an instantaneous capital gain to those who attacked the reserves.

Conversely, to demonstrate necessity, assume that net reserves have fallen to their lower bound but that there still remains an excess money supply at the current fixed exchange rate. Recall that we have assumed that the policy rule always will establish a viable, market clearing new exchange rate. If the policy rule sets \hat{e}_t less than the current fixed exchange rate, it would worsen the excess supply. Therefore, such a policy rule would contradict the assumption of money market equilibrium.

b. A Viable Devaluation Policy and the Floating Exchange Rate

To produce a viable new exchange rate, the policy rule must prescribe an exchange rate greater than or equal to the rate which would prevail in a post-attack, permanently floating exchange rate regime. In such a regime, net foreign reserves would remain permanently at \bar{R} , and the floating rate would just clear the money market. If the central bank attempted to establish a fixed rate below the floating rate when forced to devalue, it would face a demand for reserves which it could not fulfill because its reserves would already have reached \bar{R} . Therefore, the floating exchange rate places a lower bound on the value of a new fixed exchange rate. Since the underlying permanent flexible exchange rate constitutes an important building block in our model, we proceed to find its solution.³

Using the money market clearing condition, we can determine the flexible exchange rate. Substituting (2) and (3) into (1), we obtain for any time t during the floating regime

$$\tilde{h}_t = -\alpha \tilde{e}_{t+1} + [1+\alpha] \tilde{e}_t \quad (4)$$

where $\tilde{h}_t \equiv \log[D_t + \bar{R} \exp(\bar{e})] - \beta - \alpha y_t + \alpha i_t^* - p_t^* - u_t - w_t$. D_t is the domestic credit component of the monetary base at time t , and \tilde{e}_t represents the permanently floating exchange rate. We convert \bar{R} into domestic currency using the fixed exchange rate e prevailing at the time of the switch to floating rates. This follows from our assumption that the government does not repudiate its fixed exchange rate until reserves reach \bar{R} .

We denote by h_t the initial value of \tilde{h}_t which would prevail at time t if the floating rate began at t . In principle, it is important to distinguish between the stochastic process which drives future values of the \tilde{h}_t variable after the floating rate begins from the process which drives h_t . h_t is determined period after period during the operation of the fixed exchange rate system. In particular, the reserve limit \bar{R} may evolve during the fixed rate regime, thereby affecting the development of h_t . However, during a pure float the reserves entering into \tilde{h}_t would not change. In addition, variables like D_t entering into h_t may behave differently under a fixed rate environment from under a permanent float. However, since the \tilde{h}_t process is unobservable by the researcher, we will assume that the \tilde{h}_t and h_t processes are identical.

The stochastic process which drives the h_t (and \tilde{h}_t) variable is assumed to be a first-order, autoregressive process exogenous to the exchange rate. Specifically, the h_t process is

$$h_t = a_1 + a_2 h_{t-1} + v_t ,$$

where v_t is a white noise process with a normal density function $g(v)$, with zero mean and standard deviation λ .⁴ We obtain the flexible exchange rate \tilde{e}_t by solving the difference equation in (4). The solution is $\tilde{e}_t = \mu a a_1 + \mu h_t$ where $\mu = 1/[(1+\alpha) - \alpha a_2]$.

The central bank's determination of the policy rule for the new exchange rate should involve some optimization problem which produces the new fixed rate as a function of the model's state variables. We will assume that the new fixed rate is a simple linear function

$$\hat{e}_t = \tilde{e}_t + bv_t \quad (5)$$

where b is a parameter with a non-negative value. \hat{e}_t is the new fixed exchange rate which will be established conditional on reserves' falling below the level \bar{R} at time t .

Note from the solution for \tilde{e}_t that \hat{e}_t is a function of the only state variables in the model, h_t and v_t . Also, since $b \geq 0$, \hat{e}_t exceeds the minimum viable value for a new exchange rate when reserves run out.⁵ The rule (5) states that after an attack the central bank will select a new rate equal to the minimum viable rate plus a non-negative quantity dependent on the magnitude of the disturbance which forced the collapse.

c. The Probability of Attack and the Conditional Exchange Rate

In section a, we demonstrated that \hat{e}_t exceeding the current fixed rate is equivalent to the occurrence of a devaluation at time t . Therefore, the probability of devaluation at time $t+1$ based on information available at t is

$$\Pr(t+1|t) = \Pr(\mu h_{t+1} + \mu a_1 + bv_{t+1} \geq \bar{e}),$$

where \bar{e} is the time t value of the fixed rate. Alternatively,

$$\Pr(t+1|t) = \Pr(v_{t+1} > K_t) = 1 - F(K_t) \quad (6)$$

where $K_t \equiv [1/(\mu+b)][e^{-\mu a_1} - \mu(a_1 + a_2 h_t)]$, and $F(K_t)$ is the cumulative distribution function associated with $p(v)$.

Knowing this density function, agents can form future exchange rate expectations from the average of the current fixed

exchange rate and the rate expected to materialize conditional on a devaluation, both weighted by the respective probabilities of occurrence:

$$Ee_{t+1} = [1 - \text{Pr}(t+1 | t)]\bar{e} + \text{Pr}(t+1 | t)E[\hat{e}_{t+1} | v_{t+1} > K_t].$$

Using (5), the conditional expectation can be expressed as

$$E[e_{t+1} | v_{t+1} > K_t] = \mu a_1(1+\alpha) + \mu a_2 h_t + [\mu + b]E[v_{t+1} | v_{t+1} > K_t] \quad (7)$$

where

$$E[v_{t+1} | v_{t+1} > K_t] = \int_{K_t}^{\infty} v g(v) / [1 - F(K_t)] dv.$$

Since $g(v)$ is a normal density function, the unconditional forecast of the exchange rate for $t+1$ is

$$Ee_{t+1} = F(K_t) \bar{e} + [1 - F(K_t)] [\mu a_1(1+\alpha) + \mu a_2 h_t] + \lambda(\mu + b) \exp[-.5((K_t)/\lambda)^2] / \sqrt{2\pi} \quad (8)$$

The one step-ahead devaluation probability (6) and the conditional and unconditional exchange rate forecasts (7) and (8) are the main products of our model. We would expect $\text{Pr}(t+1|t)$ to peak immediately before a devaluation. Ee_{t+1} should be closely correlated with the appropriate forward or futures exchange rates. Finally, the conditional forecast should approximate the exchange rate set when a devaluation occurs.

II) The Mexican Devaluations

Section I extends speculative attack models to the problem of recurring devaluation. Since none of the existing models have been empirically oriented, we have constructed our theory in a

manner which permits its empirical implementation. In particular, we will now construct conditional expected exchange rates and a time series of the step-ahead devaluation probabilities $Pr(t+1|t)$ for the recent Mexican experience.

At the outset, the reader should be warned against interpreting our empirical results as tests of this particular theory. We intend only to consider how data may be brought to bear on the speculative attack problem, so we regard our results as indicative of the possible usefulness of this mode of theorizing.

a. General Description of the Estimation Procedure

The unconditional expected exchange rate (7) will supply the keystone of the estimation procedure. Interpreting future or forward exchange rates as unconditional expected rates, we can employ least squares methods to estimate the unknown parameters in (8).

For the empirical implementation, we found that reasonable parameter estimates were produced only by a rather elaborate three step procedure.⁶ The first step consists of estimating the parameters of the money demand equation, β , α , and ω . We next assume that the futures rates for the Mexican peso (f_t) are generated by,

$$f_t = Ee_{t+1} + x_t \quad (9)$$

where x_t is a disturbance.

Using the first step money demand parameter estimates in (8) and substituting for Ee_{t+1} in (9), estimates of \bar{R} , b , a_1 , a_2 ,

and λ were obtained by a grid search algorithm which minimizes the sum of squares residuals $[f_t - Ee_{t+1}]$. Since for any given \bar{R} value the series h_t is observable, the parameters a_1 , a_2 , and λ were estimated using ordinary least squares for each possible \bar{R} in our grid. The values of the b grid were restricted to the non-negative region. Similarly, the net reserve limit \bar{R} was restricted from falling below some minimum negative value beyond which the model would imply negative money supply values in the presence of an attack.

b. Data Problems in the Mexican Case⁷

To estimate the model's parameters, we employed quarterly data from the fourth quarter, 1973 to the fourth quarter, 1981. We were limited to quarterly data, because the forward market in pesos did not develop until after the 1976 devaluation. The peso futures market existed throughout, but it is limited to four delivery dates per year. The data used for parameter estimation purposes encompassed the 1976 devaluation but not the February and August, 1982 devaluations. However, we did substitute realized h_t values from 1982 into our estimated probability formula to examine how well our model "predicts" the 1982 episodes.

The money stock variable is the end of quarter monetary base. Alternative money concepts such as peso denominated M1 appeared unsuitable because of the pervasive currency substitution during the period. A sizable stock of domestic liabilities was denominated in dollars (mexdollars) during the sample period.⁸ Also, before the 1976 episode, the banking system's long

term liabilities could be costlessly converted to currency, which blurred the meaning of M1.

The level of domestic credit D_t is represented by the Banco de Mexico's loans to the federal government. Data for the bank's financing of the remainder of the economy are not readily available. For y_t and p_t , we used the quarterly series of logarithms of real gross domestic product and the gross domestic product deflator, respectively.⁹ For the foreign price level plus deviations in purchasing power parity, we divided the domestic price level by the current fixed exchange rate and computed the logarithm of the quotient.

Mexican capital markets were underdeveloped during most of the period and the interest rates for bank liabilities were controlled. Since there is no observable series for the short term domestic interest rate, i_t , we used the U.S. three month Treasury bill rate plus the corresponding discount of the peso in the futures market. For f_t in (8), we used the logarithm of the end-of-quarter peso rate for delivery three months forward.

Finally, the Mexican episode presents a difficulty with our assumptions about \bar{R} , the minimum allowable net reserve value. We assumed in our theoretical development that \bar{R} remains constant, regardless of the evolution of the other variables of the model. In the Mexican case, such an assumption is not tenable. First, the Mexican economy exhibited rapid growth for much of the sample period; so a minimum net reserve level which the central bank might have avoided in 1973 could easily have been chosen in 1979. Second, the real value of the dollar declined throughout the period. Maintaining any given level of net dollar reserves would

Table 1
Estimates of the Demand for Base Money Parameters

Parameter	Coefficient	Standard Error
Ω	.730	.100
α	-1.937	1.447
March	- .884	1.190
June	- .856	1.184
September	- .936	1.189
December	- .690	1.880

	Q(15)	69.73
	R**2	0.783

Q(n) is the Box-Pierce statistic.

Table 2
Estimates of the Future Exchange Rate Parameters

Parameter	Estimate
\bar{R}	-3600. (million dollars)
b	0.
a ₁	0.270
a ₂	0.909
λ	0.330

The sum of squared residuals was minimized at the corner solutions for both \bar{R} and b . Since the nature of the result precludes any reasonable standard deviation estimates for the parameter estimates, we have not reported standard errors. Thus, it is difficult to judge the quality of the estimates, based on standard sampling theory methods. We employ these results as plausible parameter values in a construction of the devaluation probability time series. We will interpret the constructed series as a kind of simulation of our model based on actual data.

Before examining the probability series, however, we wish to examine the nature of the model when it assumes the above parameter values. The zero value for b implies that the new fixed exchange rate materializing after an attack will be the permanent floating rate which would clear the money market at the time of the attack. This does not mean that the exchange rate will float permanently; if the value of the v disturbance in the next period is small enough, this new fixed exchange rate can be maintained. Since the value of the a_2 parameter implies that the h_t process is stationary, a newly established exchange rate is expected to be permanent. Only a large enough accumulation of positive v realizations will cause a new attack. Finally, the \bar{R} parameter value implies that the minimum net reserve limit in million dollars was -4734. in 1973/4 (U.S. import price index = 1.315), -7070 in 1976/3, -10,386. in 1982/4, and -10,274 in 1982/3. The corner value for \bar{R} was forced by the 1974/3 observation; an \bar{R} value lower than -3600. for this observation would have meant that base money would have fallen below zero in the event of an attack.

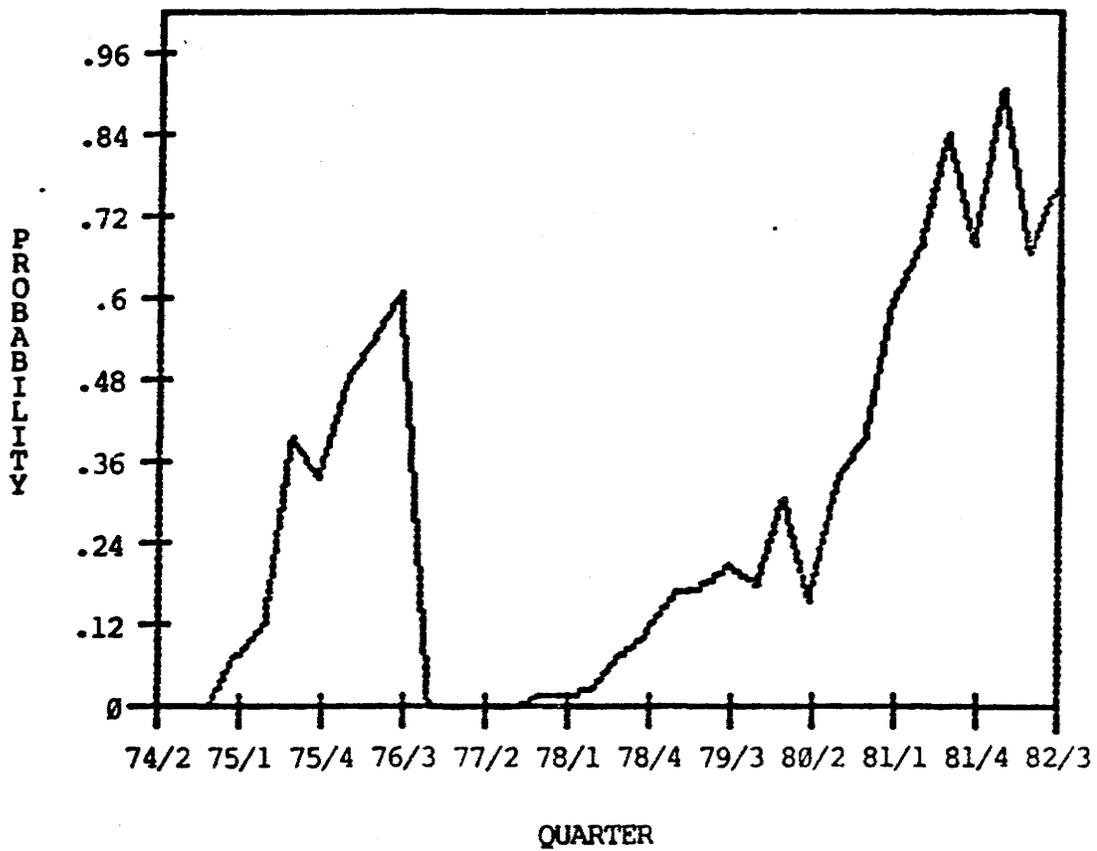
d. One Step Ahead Devaluation Probabilities

The series of one step ahead devaluation probabilities is one of the most interesting results of this exercise. We computed the series from (6) after substituting the above parameter estimates and the data associated with each observation. The series presented in Table 3 and Figure 1 indicates that the probability of devaluation one period ahead was low through the second quarter of 1975. In 1975/3 it jumped to a value of .4,

Table 3
Time Series on $Pr(t+1 | t)$

73/4	.011
74/1	.009
74/2	.000
74/3	.000
74/4	.004
75/1	.081
75/2	.135
75/3	.401
75/4	.341
76/1	.485
76/2	.544
76/3	.611
76/4	.008
77/1	.000
77/2	.000
77/3	.000
77/4	.020
78/1	.023
78/2	.033
78/3	.079
78/4	.111
79/1	.170
79/2	.184
79/3	.212
79/4	.185
80/1	.314
80/2	.162
80/3	.336
80/4	.396
81/1	.588
81/2	.675
81/3	.836
81/4	.678
82/1	.909
82/2	.668
82/3	.763

PROBABILITY OF DEVALUATION NEXT PERIOD



reaching .544 in 1976/2, the quarter before the September, 1976 devaluation, and .611 in 1976/3. The probability then declined precipitously after the 1976/3 and 1976/4 devaluations, remaining at low levels until 1978/4. The probabilities then began to rise, attaining the highest levels in the three quarters preceding the February, 1982 devaluation. Even after this devaluation of almost 100 per cent, the probability attained its highest level of .909 in 1982/1, four months before the August, 1982 devaluation. In addition to the major devaluations, mini-devaluations occurred throughout 1981. The August, 1982 devaluation was different from the others in that the Banco de Mexico resorted to exchange controls in this episode. We emphasize here that the 1982 devaluation probabilities are "out of sample" since we estimated all parameters using data only through 1981. We have calibrated the model with the data through 1981, using the results to form predictions of the time of the 1982 devaluations.

e. The Expected Exchange Rate Conditional on Devaluation

For several different quarters, we have computed the expected current quarter exchange rate conditional on a devaluation, where the expectation is based on data from the preceding quarter. We have concentrated on the quarters around the major devaluations. Explicitly, this conditional exchange rate is given in equation (7). We report these conditional rates in Table 4. For comparison we also report the fixed exchange rate that actually materialized in the period.

Table 4
Conditional and Actual Exchange Rates

Quarter	Actual Rate This Quarter	Expected Rate This Quarter Given Devaluation
76/1	12.50	15.34
76/2	12.50	15.89
76/3	19.88	16.15
76/4	20.20*	26.22
81/1	23.61	28.34
81/2	24.34	30.26
81/3	25.05	32.12
81/4	25.98	35.80
82/1	45.30	34.31
82/2	47.65	69.34
82/3	_____	62.72

*The exchange rate reached as high as 29. on November 22, 1976.

Given the relatively high conditional exchange rates during the 1981 quarters, the high probabilities of devaluation appearing in Table 1 for 1981 seem to be predicting the large devaluation that finally materialized in February, 1982. The model does not predict the slowly crawling exchange rate implemented in 1981.

We have not reported the actual exchange rate after the August, 1982 devaluation because the Mexican government imposed exchange controls for the first time in this episode. The Banco de Mexico operated a dual exchange rate. For some favored transactions the exchange rate was 49.50; for the remainder the ex-

change rate was 75.00. The predicted rate of 62.72, made for a new fixed exchange rate with no capital controls, lies between these two values.

III) Conclusion

Countries maintaining fixed exchange rates occasionally are beset by crises which force them to devalue their currencies. If such episodes recur, it is possible to use the information generated by a devaluation to construct a probability density function over the time of a future crisis. The key piece of information in such a derivation is the expected future exchange rate, composed partly of the product of the probability of future devaluation and the exchange rate conditional on devaluation.

To identify the probability of devaluation requires a theoretical model of the expected exchange rate which includes a distinct formulation of the probability. In this paper we have provided a sequence of steps with which the probabilities of devaluation can be identified and estimated. Also, the method allows us to compute expected exchange rates, conditional on a devaluation in the next period.

Employing these results in an empirical exercise for the Mexican case, we have produced a time series of endogenously driven devaluation probabilities. The probabilities of devaluation reach peak values just prior to actual major devaluations. Furthermore, the expected exchange rates conditional on devaluation are close to the values which actually materialized in the major episodes.

7 We would like to thank Armando Baqueiro of Banco de Mexico for providing most of the data.

8 See Ortiz (1981) and Ortiz and Solis (1981) for a description of the dollarization phenomenon.

9 These two series were computed by Fernando Clavijo of the Ministry of Budget and Planning using the method developed by Ginsburg (1973).

10 We employed several methods of money demand parameter estimation with more or less satisfactory results. We found that the reported result was the most satisfactory of the methods which avoided some sort of lagged adjustment model. As the Box-Pierce statistic indicates, further efforts should be made to specify the money demand model. Assuming partial adjustment of real balances would require keeping track of two initial conditions to derive the floating exchange rate solution. However, to avoid further complicating our model's dynamics, we do not pursue this problem here.

11 The grid for b consisted of 10 evenly spaced points with a maximum of 1.5 and a minimum of zero. The grid for \bar{R} contained 10 evenly spaced points with a maximum of -1000. and a minimum of -3600.

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Appendix

We derived our data from the following sources:

- D: Net financing of the federal government by Banco de Mexico—millions of pesos. This series is a proxy for the domestic credit component of the monetary base. Financing of financial intermediaries by Banco de Mexico and the 'net position:other concepts' figures were not available for the whole sample period. Source: Banco de Mexico.

- f: Logarithm of the end-of-quarter rate of pesos for delivery three months forward. Source: International Money Market Yearbook published by the Chicago Mercantile Exchange, various issues

- m: Logarithm of the end of quarter monetary base in millions of pesos. Source: Banco de Mexico, various issues.

- i*: Interest rate on three months Treasury bills in percent per quarter. Source: Federal Reserve Bulletin, Board of Governors of the Federal Reserve System, various issues.

- p: Logarithm of the implicit price deflator of the GDP for Mexico. quarterly data generated by the interpolation method of Ginsburg(1973).

- : Logarithm of the implicit price deflator of the U.S. imports of goods and services. Source: Business Statistics, Bureau of Economic Analysis, Department of Commerce.

- y: Logarithm of GDP of Mexico in real terms. Quarterly data generated by the interpolation method of Ginsburg(1973).

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