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# Self-Fulfilling Risk Predictions: An Application to Speculative Attacks

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## Abstract

The paper shows that changing market beliefs about currency risk can generate a self-fulfilling speculative attack on a fixed exchange rate. The attack does not require a later change in policies to make it profitable. This is illustrated by introducing an endogenous risk premium into a "first-generation model" of a speculative attack. The model is further modified to take account of sterilization, debt-financed fiscal deficits, and anticipatory price-setting behavior. The model is used to interpret the 1994 Mexican peso crisis.

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Contents

## SUMMARY

In some "second-generation models" of currency crisis, attack-conditional policy expansion can pull a country off a fixed exchange rate even if the country follows appropriate policies beforehand. But the empirical support for this view is limited.

This paper suggests that currency crises may be obtained entirely through private speculative behavior and do not depend on the government's policy response to private behavior. Specifically, currency crises can result from self-fulfilling shifts in speculative opinion about exchange-market risk.

To illustrate this point, the paper incorporates an endogenous risk premium into asset returns. The risk premium introduces a nonlinearity into asset markets and provides a mechanism through which multiple equilibria can occur even when policy is invariant to an attack. An endogenous risk premium is embedded in a modified "first-generation model." Like the standard first-generation model of a speculative attack, the modified model emphasizes the role of deteriorating fundamentals in making the economy vulnerable to attack. It focuses also on the profit opportunities for speculators and shows that speculation is profitable if the exchange rate that would prevail after an attack—the "shadow exchange rate"—is greater than the fixed exchange rate. The model departs from the standard first-generation model not only in its introduction of a time-varying stochastic risk premium, but in ways that help the model replicate the Mexican experience.

A sudden belief of increased risk on the part of private investors will alter the shadow exchange rate used to calculate the profitability of a speculative attack and possibly lead to self-fulfilling speculative attack.

## I. Introduction

Currency crises in Europe and Mexico, as well as those unfolding in Asia, have renewed efforts to understand and control the forces underlying speculative attacks on fixed exchange rates. Until the European crises in 1992-93, there was general agreement about the underlying cause of speculative attacks. A country would ultimately face an attack if it ran macroeconomic policies inconsistent in the longer term with the fixed exchange rate. For example, if a government monetized a large fiscal deficit, excessive money growth would cause its international reserve holdings to decline and eventually trigger an attack by speculators. The government would be forced to abandon the fixed exchange rate and let the currency depreciate. The view that deteriorating fundamentals led to currency crises was formalized in a set of "first-generation" crisis models.[1]

The European experience and the 1994 Mexican peso crisis forced economists to rethink the cause of speculative attacks. Many of the European countries, and later Mexico, were running fairly disciplined macroeconomic polices when their currencies were attacked. If inconsistent macroeconomic policies were not in place to *push* an economy toward a currency crisis, what could cause an attack?

Some economists have suggested that attack-conditional policy expansion can *pull* a country off a fixed exchange rate even if the country follows appropriate policies beforehand. The attack is self-fulfilling because post-attack policy expansion validates speculators' prior beliefs that the currency will depreciate. Multiple equilibria are possible when policy responds endogenously to an attack. The economy can find itself in a no-attack equilibrium, where the government maintains the fixed exchange rate and appropriate domestic policies, or the economy can suddenly face an attack equilibrium, where *ex-post* policy changes justify the speculative behavior.

This alternative view of currency crises has been formalized in set of "second-generation" models.[2] While these models are to be credited with expanding our ideas about the causes of currency crises, their requirement that post-attack policies become more

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[1]A notable example is Krugman (1979), whose work was inspired by Salant and Henderson (1978) and simplified by Flood and Garber (1984a). A survey of these models is provided in Agenor, Bhandari and Flood (1992).

[2]See, for example, Obstfeld (1986) and Eichengreen and Wyplosz (1993). These models build on an idea suggested by Stephen Salant in private correspondence and formalized by Flood and Garber (1984b). Second-generation models with different features can be found in Obstfeld (1994, 1997), Calvo (1995), Jeanne (1997), Bensaid and Jeanne (1995) and Sachs, Tornell, Velasco (1996). See Flood and Marion (1997) for an overview.

expansionary is problematic. Empirical support for such a policy response is far from overwhelming (Eichengreen, Rose and Wyplosz, 1995).[3]

This paper argues that currency crises may result from self-fulfilling shifts in speculative opinion about exchange-market risk rather than post-attack policy expansion. To illustrate this point, we incorporate an endogenous risk premium into asset returns. The risk premium introduces a nonlinearity into asset markets and provides a mechanism through which multiple equilibria can occur even when policy is invarient to an attack. Indeed, multiple equilibria are obtained entirely through private speculative behavior and do not depend on the government's reaction to private behavior.

We embed the endogenous risk premium in a model that retains key features of the first-generation model but also departs from it in several ways. We therefore consider our model to be a "modified first-generation model."

We adopt the first-generation model's focus on speculators and the profits available to them. Currency crises do not occur if there is no profit for speculators. Once profit opportunities appear, speculators pounce. In the model, speculation is profitable if the exchange rate that would prevail after an attack—the "shadow exchange rate"—is greater than the fixed exchange rate.

We depart from the standard first-generation model in four ways. The first departure allows us to introduce the possibility of multiple equilibria. The other three help us replicate the Mexican experience.

Our first departure is the introduction of a stochastic, time-varying risk premium in the interest parity condition. The risk premium reflects the risk attached by the foreign investor to domestic-currency assets. If these agents suddenly perceive more post-attack risk, it can increase the chance of a speculative attack. This is because the amount of perceived risk affects the value of the shadow rate used to determine the profitability of an attack. If agents come to expect increased exchange-rate variance in a post-attack environment, the change in expectations magnifies the variance of the underlying stochastic disturbance and thereby increases the actual exchange-rate variance of the shadow exchange rate. Moreover, because of volatile beliefs about currency risk, the relationship between the attack and fundamentals is not uniquely determined.[4]

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[3]It might be argued that the post-attack depreciation itself is the relevant expansionary policy. That argument requires either that the real exchange rate be misaligned prior to the depreciation, which would be a fundamentals problem, or that domestic prices be increased after the depreciation, which would show up as a post-attack policy validation.

[4]Driskill and McCafferty (1980) were among the first to note the implications of incorporating

(continued...)

Our second departure involves recognizing that the monetary authority may be constrained from undertaking a strong defense of the fixed exchange rate by other domestic considerations. We model these constraints by assuming the monetary authority continually sterilizes the effects of international reserve changes on the monetary base. Consequently, there is no decline in the monetary base during a speculative attack and no change in the money growth rate after the attack. Such sterilization operations accord well with actual events in Mexico.[5]

Our third departure relates to the financing of the fiscal deficit. While we retain the assumption that the country runs a fiscal deficit, we depart from the standard first-generation model by having the fiscal deficit be bond-financed rather than monetized. More importantly, the amount of bond financing need not be so large as to make a currency crisis inevitable. Our choice of financing strategy can make the economy increasingly vulnerable to an attack and seems appropriate for Mexico.

Our fourth departure is to relax the assumption of purchasing power parity. Instead, we assume that goods prices are set a period in advance at a level that is expected to clear the market. This price-setting behavior greatly simplifies our risk premium derivation since portfolio holders can ignore goods-price variance and concentrate on exchange-rate variance. In addition, since prices can rise before an attack in anticipation of future currency depreciation, the model mimics both the appreciation of the real exchange rate and the increase in the domestic interest rate that precede a currency crisis like the one in Mexico.

The rest of the paper is organized as follows. In Section 2, we describe the model in more detail. We specify the economy's asset markets and goods markets and the assumptions about government policy. In Section 3, we identify the conditions under which a speculative attack takes place. To do so, we solve for the shadow exchange rate and find that it has multiple solutions. Multiple solutions give rise to the possibility of self-fulfilling speculative

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[4](...continued)
a risk premium in asset returns.

[5]This point is discussed further in Section 4. When sterilization is incorporated into the standard first-generation model, it makes a fixed exchange rate extremely precarious regardless of the amount of international reserves available to the authorities or the behavior of other economic fundamentals. For example, Flood, Garber and Kramer (1996) show that in the traditional first-generation model where domestic-currency bonds and foreign-currency bonds are perfect substitutes, if the public knows an attack on the fixed exchange rate regime will be sterilized completely, the fixed rate regime will be stillborn regardless of the exchange rate chosen for fixing and the size of the finite reserve stock committed to preserving the fixed exchange rate. Consequently, we allow for imperfect substitutability between domestic and foreign-currency bonds when the central bank sterilizes fully.

attacks driven by changing perceptions about risk. In Section 4, we examine how well our model captures some features of the 1994 Mexican currency crisis.

## II. The Model

The model is a stochastic, discrete-time model of an open economy with a fixed exchange rate. Agents have rational expectations and know the fixed exchange rate will be abandoned should the central bank run out of reserves.[6] There is uncertainty about fundamentals, and this uncertainty influences asset returns and price-setting behavior. We now turn to the specification of the asset markets.

### A. Asset Market Structure

The principal equations of the model are:

$$m_t - p_t = -a\, i_t + \delta\epsilon_t \,; \qquad a>0,\ \delta \gtrless 0 \tag{1}$$

$$i_t = i_t^* + E_t(s_{t+1} - s_t) + \theta_t(c + b_t - b_t{*} - s_t) \tag{2}$$

Equation (1) describes the domestic money market, where $m_t$ is the log of the domestic high-powered money supply, $p_t$ is the log of the domestic price level, and the demand for real money balances depends negatively on the domestic interest rate, $i_t$.[7] Money demand is also influenced by a real shock, $\epsilon_t$.

Equation (2) is the interest parity condition. Let $s_t$ be the log of the exchange rate, quoted as the domestic-currency price of foreign exchange. Then the domestic interest rate deviates from the foreign interest rate, $i_t$*, by the expected rate of change of the exchange rate, $E_t$ ($s_{t+1}$-$s_t$), plus a time-varying risk premium, $\theta_t$ (. . .).

The risk premium is influenced by the relative private holdings of domestic and foreign government securities, agents' attitudes towards risk, and uncertainty about the future

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[6]With a bit more structure we could have the attack end in devaluation.

[7]Nothing substantive is altered by using domestic prices as the deflator for nominal money balances rather than the weighted average of domestic prices and the domestic-currency value of foreign prices. Using the home goods price level as the deflator corresponds to Dornbusch (1976).

exchange rate. The term $(b_t - b^*_t - s_t)$ describes the world-wide relative private holdings of government securities, where $b_t$ is the log of world-wide private holdings of domestic government securities and $b_t^* + s_t$ is the log of world-wide private holdings of foreign government securities expressed in domestic-currency terms.[8]

The term $\theta_t$ summarizes how desired asset holdings are influenced by tastes toward risk and uncertainty about returns. In the example developed below, $\theta_t = zV_t(s_{t+1})$, where z is proportional to a measure of risk aversion and $V_t$ is the variance operator conditional on information available at time t.[9]

$\theta_t(\ldots\quad)$ is a tractable log approximation of elements that may influence attitudes toward asset risk. It has the following properties: (1) in a world of certainty ($V_t(.) = 0$) or risk neutrality ($z = 0$), the risk premium is zero; (2) the constant c is sufficiently large to ensure that a bigger $\theta$ increases the risk premium; and (3) neither aggregate world wealth nor country shares in world wealth are important determinants of the risk premium.

### B. Goods Market Structure

Households consume both domestically-produced goods and imported goods. We assume $p_t$, the domestic price of domestically-produced goods, is set at time t-1 at a value that is expected to clear the market for home goods at time t. If the excess demand for home goods depends on relative prices and the foreign price level and other influences on excess demand are normalized to zero in logs, the expected market clearing price for home goods is:

$$p_t = E_{t-1}s_t \tag{3}$$

The price of domestically-produced goods will change only if agents anticipate a change in the exchange rate.

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[8]The assumption that the risk premium responds to relative supplies of government debt is familiar from the portfolio-balance models of Tobin (1969) and Branson (1968) and was tested by Frankel (1984), Black and Salemi (1988) and others. The assumption has not found much empirical support. Werner (1996), however, has found such a risk premium works well for Mexico during the 1992-94 period.

[9]Our risk premium is based on a model where the foreign investor maximizes expected welfare that depends positively on expected future wealth and negatively on the variance of future wealth relative to current wealth. Since the variance of future wealth depends on the variance of the future exchange rate, the risk premium is affected by expected exchange-rate variance. For details of the derivation of the risk premium, see the appendix.

## C. Asset Accounting

We now turn to the government's balance sheets. Before a speculative attack, the domestic high-powered money supply is equal to domestic credit plus the book value of international reserves held by the central bank. An attack causes international reserves to fall to their lower bound, which we set at zero for simplicity.[10] After the attack, the high-powered money supply is simply equal to domestic credit.

It is useful to specify the bond market first in levels of the variables and then move to the appropriate log-linearization. The outstanding supply of domestic-currency government bonds is denoted by $H_t$. World-wide private holdings of these bonds are $B_t$ and the domestic monetary authority's holdings of these bonds are denoted as domestic credit, $D_t$. Letting $h_t = \log H_t$, $b_t = \log B_t$, and $d_t = \log D_t$, the log-linearization of the bond market is: $b_t = \gamma h_t + (1-\gamma)d_t$, where $\gamma>1$ is the ratio $H_t/B_t$ at the point of linearization. After a successful attack on the currency, $d_t = m_t$ in the bond-market equation.

One final piece of structure involves the underlying exogenous process driving the economy. We assume real government expenditure is financed partly by issuing nominal government bonds and partly by levying taxes. Taxes increase with the stock of outstanding government bonds so that the deficit does not grow without bound and transversality conditions apply.

Recalling that $h_t$ is the log of outstanding interest-paying nominal claims on the domestic government, let these bonds follow the process:

$$h_t = \mu + \rho h_{t-1} + \varepsilon_t; \quad u>0, \quad 0<\rho<1, \tag{4}$$

where $\mu/(1-\rho)$ is the steady state of domestic bonds, $\rho$ is the degree of autocorrelation in the bond process, and $\epsilon_t$ is the shock to the bond process.

The shock can signify one of several disturbances. For example, a negative productivity shock that reduces tax revenues will cause bond financing to increase unexpectedly, and this disturbance permanently feeds into the bond process to cover next period's unexpectedly higher interest payments. The negative productivity shock also reduces the demand for money, so in this example the parameter $\delta$ in the money demand function is negative. The shock to the bond process can also arise from an unexpected increase in government expenditures that is financed in part by bond sales. In this case, the disturbance increases the demand for money, so the parameter $\delta$ in the money demand function is positive.

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[10]Buiter (1987) endogenizes this lower bound, as do Flood and Marion (1997).

Notice that $\epsilon_t$ is the only stochastic element in the model.[11] The precise distribution of $\epsilon_t$ will turn out to be crucial, but we will turn to that later.

### D. Government Policy

We postulate lexicographic government preferences concerning the fiscal deficit, monetary policy and the fixed exchange rate. The fixed rate , $\bar{s}$, gets the lowest priority. When international reserves hit their lower limit, the government decides against borrowing reserves or changing domestic interest rates. Instead, the fixed rate is abandoned and the exchange rate is allowed to float freely thereafter.[12]

The monetary authority alters its holdings of government securities to keep the domestic high-powered money supply constant. This policy requires full sterilization of international reserves prior to the attack. The policy is maintained even if there is a speculative attack. Thus $m_t = \bar{m}$ both before and after an attack.[13] Although having policy become more expansionary after a speculative attack is an essential feature of second-generation models, Eichengreen, Rose and Wyplosz (1995, 1996) find no consistent pattern in a cross-section of country experiences. Consequently, while the government lets the exchange rate float freely after a successful attack, we assume other government policies are invariant to the attack.

## III. What Triggers An Attack?

If domestic bond expansion exceeds foreign bond expansion, then over the longer run it will become increasingly difficult to maintain a fixed exchange rate since portfolio reallocation by the private sector will drain international reserves. The crucial question, of course, is when will the fixed exchange rate break down?

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[11]We could incorporate many different types of shocks, but doing so would increase the dimensionality of the problem and make it impossible to graph our results.

[12]In our model, foreign bond expansion is zero and the domestic bond supply reaches a steady-state level that may or may not make an attack inevitable. Recall that the lower limit on the reserve level is set at zero. Endogenizing the lower limit need not affect the main results.

[13]This feature differs from Flood, Garber and Kramer (1996) in which the attack itself is sterilized, but the attack results in a discrete expansionary shift in monetary policy. In many real-world episodes, however, monetary policy is invariant to the attack and there is no policy expansion after the attack.

The simple answer is that it will break down whenever it is worthwhile for speculators to attack the currency, and that will happen when speculators believe the foreign exchange they buy from the central bank at a fixed price can immediately be resold at a higher price.

Following Flood-Garber (1984a), define the shadow exchange rate, $\tilde{s}$, to be the rate that would prevail at time t if the fixed exchange rate were attacked, international reserves were driven to their lower bound, and the exchange rate were allowed to float freely thereafter. The condition for an attack is that the shadow rate exceed the fixed rate ($\tilde{s}_t > \bar{s}$). We must therefore solve the model for the shadow exchange rate and determine when it exceeds the fixed rate.

Since the domestic price level is tied to beliefs about the exchange rate that were formed in the previous period, it follows from equation (3) that:

$$p_t = (1-\pi_{t-1})\bar{s} + \pi_{t-1}E_{t-1}(\tilde{s}_t \mid \tilde{s}_t > \bar{s}), \tag{5}$$

where $\pi_{t-1}$ is the probability at time t-1 that an attack will take place at time t and $E_{t-1}(\tilde{s}_t \mid \tilde{s}_t > \bar{s})$ is the t-1 expectation of next period's (flexible) exchange rate, conditional on the exchange rate exceeding $\bar{s}$ so the attack occurs. The probability estimate and the conditional expectation of the exchange rate change with the state of the economy.

To aid in solution of the shadow rate, we linearize the cumulative distribution for the stochastic variable $\varepsilon$ by assuming $\varepsilon$ has a uniform distribution centered on zero with upper bound w and lower bound -w. Formally, if $f(\varepsilon)$ is the probability density associated with the outcome $\varepsilon$, then

$$\begin{aligned} f(\varepsilon) &= 0 \ ; \quad \varepsilon<-w, \quad \varepsilon > w \\ f(\varepsilon) &= 1/(2w) \ ; \quad -w\leq\varepsilon\leq w \end{aligned} \tag{6}$$

### A. Solving for the Shadow Rate

Since the model is linear in the post-attack period, we propose a linear solution for the shadow exchange rate of the form:[14]

$$\tilde{s}_t = \lambda_0 + \lambda_1 h_{t-1} + \lambda_2 \varepsilon_t. \tag{7}$$

[14]Post-attack, exchange-rate variance is constant. There is still a slight transition-related nonlinearity, but we approximate it in equation (A.16) of the appendix.

The solution method is described in the appendix. It exploits the assumption that the stochastic variable $\epsilon$ has a uniform distribution. The solution for the shadow rate in (7) is:

$$\lambda_0 = \textit{a constant term} \quad (\textit{see appendix}) \tag{8}$$

$$\lambda_1 = \frac{\alpha\rho[\theta_t\gamma+\beta_1]}{[\alpha(1+\theta_t)+\frac{\bar{\pi}}{2}+\frac{1}{4}]} \geq 0 \tag{9}$$

$$\lambda_2 = \frac{\gamma\theta_t - \frac{\delta}{\alpha} + \beta_1}{(1+\theta_t)} \tag{10}$$

where $\beta_1$ is the unknown variable in a fifth-order polynomial and is discussed more fully in the appendix.

Ignoring values for $\lambda_1$ and $\lambda_2$ that are imaginary and hence are not economically sensible leaves the possibility of three solutions for the shadow exchange rate for a range of parameter configurations. Nothing seems to preclude any of these solutions.[15]

The most important nonlinearity that produces these multiple solutions involves the disturbance term. The disturbance term enters money demand with coefficient $\delta$ and it enters the risk premium with the coefficient $\theta_t\,\gamma$. The composite disturbance is therefore $(\delta-\alpha\theta_t\gamma)\varepsilon_t$. Since $\theta_t$ is proportional to exchange-rate variance, an increase in perceived variance (a bigger $\theta_t$) can magnify shocks and increase actual exchange-rate variance.

In the special case where the disturbance to the bond process is uncorrelated with money demand ($\delta$=0), the money market is nonstochastic. The disturbance $\varepsilon$ does not enter money demand additively nor does it enter through the risk premium, since when $\delta$=0, $\theta$=0 as well. When $\delta$ is zero, one of the three values for the shadow exchange rate is a constant. We refer to this solution as the *market fundamentals solution*. Depending on parameter values, this market fundamentals solution may be less than the fixed exchange rate, in which case an

[15]In the appendix, we describe in more detail these three solutions for the shadow exchange rate. All three solutions are rational expectations equilibria. That is, they are solutions for which beliefs about exchange-rate variance and actual exchange-rate variance coincide.

attack never occurs, or it may be above the fixed exchange rate, so that the attack occurs right away. The other two shadow-rate solutions can be classified as "second-moment bubbles." These bubbles involve self-fulfilling beliefs about exchange-rate variance and are not to be confused with the more familiar first-moment bubbles that come about when the exchange rate today depends on the expected future exchange rate. Standard first-moment bubbles are excluded by assumption. In contrast to first-moment bubbles, these second-moment ones have no explosive intertemporal dimension and do not violate transversality conditions.

Because the model yields three solutions for the shadow exchange rate, there is the potential for multiple equilibria even though government macroeconomic policies remain invariant to the speculative attack. If agents expect more currency variability, it affects the domestic interest rate through the interest parity relation and feeds into the asset markets in a way that will make the exchange rate more variable should the fixed rate be abandoned. That, in turn, alters the shadow exchange rate used to determine whether an attack is profitable to undertake.

### B. A Numerical Example

Obtaining solutions for the shadow rate involves solving a constant-coefficient polynomial of order five. Since such a polynomial generally does not have explicit reduced-form solutions for the roots in terms of the constant coefficients, we resort to numerical methods.[16]

Suppose the shocks to money demand and bond supply are negatively correlated. Let $\delta = -0.025$ and set.[17]

$\alpha = 1$ (the semi-elasticity of money demand with respect to the interest rate)

$\rho = .9$ (autoregressive coefficient in the bond supply process)

$\mu = 1$ (the steady state stock of domestic government bonds is $\mu/(1-\rho)$.)

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[16]The parameters are set to establish an example of the existence of viable multiple equilibria. They are not proposed as estimates from any particular data set.

[17]In addition to the parameters listed below, variables such as $i^*$, $\bar{s}$, $b^*$, and $\bar{m}$ must be set in order to determine the constant terms $(\lambda_0)$ in the shadow rate equation (7). The variable $b^*$ is treated as a constant because it is assumed that central bank sales of foreign securities to agents speculating against the domestic currency are small relative to the worldwide holdings of these securities. The Gauss program used to extract the roots and draw the shadow-rate solutions in Figure 1 is available from the authors.

$\gamma = 1.1$ (implying that domestic credit held by the central bank accounts for about 10 percent of the debt issued by the domestic government)

$z = 2$ (risk aversion parameter)

$w = 2$ (the bound of the uniform shock distribution)

$\sigma_\varepsilon^2 = \frac{w^2}{3}$ (the variance of the shock $\varepsilon$ that is uniform on (-w, w)).

The example is pictured in Figures 1. The figure summarizes the most important aspects of a three-dimensional figure drawn in $(\tilde{s}_t, h_{t-1}, \varepsilon_t)$ space. The three-dimensional picture (not drawn) consists of four planes. With $\tilde{s}_t$ as the vertical axis, the first plane is flat at the height $\tilde{s}_t = s$. Call this the $\bar{s}$ plane. The other three planes are found by plotting equation (7) for the three different real values of the $\lambda_i$'s. These planes are upward-sloping with respect to both $h_{t-1}$ and $\varepsilon_t$. Call these planes the $\tilde{s}_t$ planes. The "tabletop" rectangle in Figure 1 is the view obtained from looking down on the $\bar{s}$ plane, where the horizontal axis on the $\bar{s}$ plane is centered on zero and measures 2w in length to conform with the uniform distribution of $\varepsilon$. The three lines on the tabletop indicate where the three $\tilde{s}$ planes cut through the $\bar{s}$ plane; that is, the points in $(h_{t-1}, e_t)$ space where the three shadow exchange rates equal the fixed exchange rate. Line (a) is the locus of points where the low-variance shadow-rate solution equals the fixed exchange rate, while line (c) is where the highest-variance shadow-rate solution equals the fixed rate. Note that when $\delta<0$, the three lines on the $\bar{s}$ plane have different negative slopes.

The key point illustrated by Figure 1 is that a $\tilde{s}$ plane can cut the $\bar{s}$ plane in one of three places. If the economy's state (determined by h and $\epsilon$) is below all three lines, then there can be no attack because none of the $\tilde{s}$ planes has yet cut through the $\bar{s}$ plane. If the state is above all three lines, then there must be an attack because all of the $\tilde{s}$ planes are above the $\bar{s}$ plane.

Suppose agents expect the low-variance shadow-rate solution represented by line (a) and that the state is somewhere in the region bordered by lines (a) and (c), having cut through the $\bar{s}$ plane at line (c). Here we have the possibility of multiple equilibria. The economy can maintain the fixed exchange rate as long as agents continue to expect a low-variance shadow rate. But if agents suddenly come to expect the high-variance shadow rate, there would be an immediate and successful attack since the high-variance shadow exchange rate already exceeds the fixed exchange rate.

Thus if agents suddenly revise their expectations because they believe the foreign-exchange market has become riskier, the fixed exchange rate can collapse, producing after the collapse the risk anticipated by the agents. It should be clear, however, that this possibility of a self-fulfilling collapse can only occur for certain states of the economy. For instance, if the economy's fundamentals are very sound, so that the state is in the "no-attack zone" below the $\bar{s}$ plane, then even if agents suddenly come to believe the world is riskier, the fixed exchange rate will not collapse. Only if the economy's fundamentals deteriorate sufficiently to put the state in the "possible attack zone" (above line (c) but not yet above lines (a) and (b)) could a sudden adverse shift in expectations about risk trigger an attack.[18] [19] Note also that in this "possible attack zone" the collapse is initiated by a change in agents' beliefs about risk and does not require an *ex-post* change in government stabilization policies.

To summarize, the existence and relevance of multiple equilibria depend on (1) having the appropriate parameter values to give multiple real values for $\lambda_2$, (2) having agents adopt the low-variance shadow rate solution at the start, and (3) having the state take on a value such that the economy finds itself in the "possible attack" zone.

Multiple equilibria can be excluded if (1) the parameters of the model do not give multiple relevant solutions for the shadow rate, or (2) if the pre-attack state is not in the "possible attack zone." For example, in this model if $\theta$ is constant, then there are no multiple equilibria.

In this framework, a speculative attack can be caused by poor fundamentals because the state puts the economy into the "attack zone." Alternatively, the attack can be caused by a self-fulfilling shift in expectations because the state puts the economy into the fragile "possible attack" zone and agents suddenly shift from the low-variance shadow rate solution to a higher-variance one. It is not the case that any fixed exchange rate regime is subject to successful attack. Fundamentals must put the economy in the fragile zone.[20]

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[18]See Velasco (1997) for another model where multiple equilibria can occur only for some range of fundamentals.

[19]Our linearization of the bond market is a tight (calculus) argument only in an infinitesimal neighborhood of the point of linearization, yet we consider the possibility that bonds issued by the domestic government, h, may change enough to move the economy from a no-attack zone to an attack zone. If the change in h is a big change—although it might equally well be very small—the linearization may not be appropriate. Moreover, the attack itself may result in a large change in private versus government holdings of domestic bonds. Hence linearization at the beginning of the crisis may be quite different from linearization once the crisis has run its course. To address this issue without undertaking a complete simulation, we re-solved the model's crucial polynomial for a range of values of the parameter, $\gamma$, that is constrained to be above one in the linearization of the bond market. For $\gamma$ between 1.05 and 1.5, the fifth-order polynomial still had three real root solutions. We report results for $\gamma$=1.1 in the text.

[20]In principle, the framework sometimes permits us to distinguish between an actual attack caused by fundamentals and one caused by a self-fulfilling shift in expectations. If we use data to estimate the lambdas and find that the economy was at the low-variance shadow-

(continued...)

## IV. The Mexican Experience

In this section, we consider how well some aspects of the Mexican experience are captured by our model. We focus on five areas: sterilization policy, interest rates, real exchange rates, international reserves and multiple equilibria.[21]

### A. Sterilization Policy

The standard first-generation model assumes that the net domestic credit component of the monetary base is exogenous and unaffected by activity in the foreign-exchange market. International reserves are merely the residual that balances the domestic money market at the fixed exchange rate. At the time of the attack, there is a discrete drop in the money supply that reflects the sudden depletion of reserves.

The Mexican story was different in the 1992-1994 period. Both before and during the exchange-rate crisis, the authorities sterilized reserve losses, keeping the monetary base on a relatively smooth trend (see Figure 2). Our model captures this policy stance by assuming the monetary authority sterilizes fully to keep the monetary base at the desired level before, during and after the speculative attack.

The sterilization policy also sets the stage for the attack by tying the hands of policymakers. After the Colosio assassination, the Mexican authorities could have defended the peso by tightening monetary policy or passively allowing the loss of international reserves to contract the monetary base. The government resisted monetary contraction in part because higher interest rates would have strained an already vulnerable banking system and conflicted with the goal of promoting economic activity in an election year. We capture these domestic constraints in a general way by requiring the central bank to keep the monetary base constant even as reserves decline.

### B. Interest Rates

In the traditional first-generation model with perfect foresight, the nominal domestic interest rate is constant until the moment of attack. With uncertainty, the domestic interest

(...continued)
rate solution at the attack time, then the speculative attack was due to fundamentals. If the estimated lambdas indicate that the economy was at the high-variance shadow-rate solution, then the attack could have been brought on by fundamentals or by a sudden shift from the low-variance shadow-rate solution.

[21]Our description of the stylized facts draws heavily on IMF (1995).

rate rises with the approach of the attack because the conditional expected rate of change of the exchange rate rises as reserves are depleted.

The behavior of Mexican interest rates prior to the attack follows an interesting pattern. Figure 3 presents three-month rates on cetes, Tesobonos, and U.S. treasury bills. Cetes are peso-denominated Mexican government securities, while Tesobonos are peso-denominated Mexican government securities with the principal indexed to the U.S. dollar exchange rate. In early 1994, cetes interest rates were around 10 percent. They moved up to the 14-17 percent range in April, increasing the spread over Tesobono rates and U.S. treasury bill rates. However, these interest differentials narrowed somewhat in the second half of 1994 before shooting up at the time of the attack in December. The interest-rate differential between Tesobonos and U.S. treasury bills also widened after the Colosio assassination in March, 1994, narrowed after Zedillo was elected president in August, and shot up again at the attack time in December. The interesting feature of interest-rate behavior is that the market did not demand a very large premium for peso lending in the second half of 1994. Some observers have taken this pattern to mean that the currency crisis was unexpected by the markets.

In our model, the spread between the interest rate on domestic-currency assets and the risk-free foreign interest rate is accounted for not only by the expected rate of depreciation of the exchange rate, but by a time-varying stochastic risk premium. The risk premium depends in part on the relative supplies of interest-bearing domestic and foreign securities in the portfolios of the private sector. Suppose that in the period leading up to the speculative attack, private investors come to expect a depreciation of the domestic currency. By itself, that will raise domestic interest rates above the risk-free foreign interest rate as private investors sell domestic securities and purchase foreign securities. But since this portfolio reallocation entails a loss of international reserves, the central bank sterilizes the reserve loss by purchasing domestic securities. Consequently, the outstanding stock of domestic securities held by the private sector declines and one component of the risk premium falls. Thus, on net, the interest rate on domestic-currency assets might rise very little. Private investors also seemed to moderate their views about an expected depreciation of the peso in the summer of 1994, as evidenced by the narrowing spread between rates on cetes and Tesobonos in July. Since the model incorporates a time-varying probability of collapse that is influenced by investors' perceptions of risk, it can allow for an adjustment in expectations that gives lesser weight to the chance of a devaluation.

### C. The Real Exchange Rate

In the standard first-generation attack model, the country experiencing an attack is a price taker and its real exchange rate, the domestic price level divided by the product of its trading partner's price level and the fixed exchange rate, is presumed to be fixed.

In Mexico, a large movement occurred in the real exchange rate after fixing the nominal rate because domestic inflation, while declining, exceeded inflation in its major trading partner(s). Figure 4 shows that Mexico's real effective exchange rate appreciated significantly after the peso was controlled in 1988. Our model gets the real appreciation in the pre-attack period, but not through inflationary monetary policy. By allowing home-goods prices to be set a period in advance, domestic prices can rise prior to the attack if agents come to expect a depreciation of the home currency. Real exchange-rate appreciation via inflationary monetary policy can take place if we relax the assumption of a constant monetary base and instead allow the monetary base to grow faster than its foreign counterpart. Such a modification is a straightforward extension but is not explored here for simplicity.

### D. International Reserves

The first-generation attack model shows that international reserves decline in the period leading up to the currency crisis and fall precipitously at the time of attack as the central bank makes a last-ditch effort to defend the fixed exchange rate. The underlying reason for the reserve loss is the excess supply of money produced by monetization of the fiscal deficit.

Figure 5 shows gross and net Mexican international reserves since 1990. Net reserves built up over the 1990-93 period, reaching a peak of $25 billion in February, 1994. Subsequently, there was a dramatic decline. More than $3 billion in reserves was lost in March; more than $8 billion in April. After a lull, $4.5 billion was lost in November and finally $6.5 billion in December.

Our model captures the decline in reserves in the period leading up to the attack even though there is no monetization of the fiscal deficit. Instead, the government's bond-financing leads private investors to reallocate their portfolios. When private investors sell domestic securities for foreign securities, the central bank must exchange reserves for domestic currency at the fixed exchange rate. Consequently, the central bank's inventory of international reserves declines. If the central bank also sterilizes this reserve loss, the domestic interest rate may not rise sufficiently to coax private investors to hold the outstanding stock of domestic securities. As a result, portfolio reallocation efforts may continue, further draining reserves. The government's debt financing also generates expectations of a future currency depreciation that stimulates portfolio reallocation and drains reserves. If speculative opinion suddenly shifts, with investors perceiving more risk, there will be a massive portfolio reallocation that exhausts reserves and ends the central bank's ability or desire to defend the fixed exchange rate.

### E. Multiple Equilibria

We have developed a model in which we can observe shifts in exchange-rate volatility even though there is no change in the underlying process driving fundamentals. In the model, it is possible that the mere perception of increased currency risk can alter behavior in a way that validates the perception. During a fixed exchange-rate period, surprising volatility in the (unobserved) shadow exchange rate translates into instability of the fixed-rate regime. More generally, volatile beliefs about exchange-rate risk may help explain why empirical models of exchange-rate determination have difficulty establishing a reliable relationship between the exchange rate and underlying fundamentals. The economy can be at the market fundamentals solution for the exchange rate, or changes in speculative opinion can shift the economy to another exchange-rate solution.

Were self-fulfilling risk predictions partly responsible for the 1994-95 Mexican crisis? Many aspects of the model just recounted match up with data reasonably well. Certainly there was a large shift in speculative opinion about the riskiness of Mexican investments. That shift coincided with an attack on the fixed-rate parity. While it seems possible that Mexico faced a self-fulfilling attack due to changed risk perceptions, producing a complete answer will require careful empirical work.[22]

## V. Conclusion

The first-generation model of currency crises relies on deteriorating fundamentals as the underlying cause of speculative attacks. It emphasizes that speculators trigger the attack in anticipation of large capital gains. It also puts reserve movements center stage, capturing their steady decline prior to an attack and their sudden depletion during an attack. Our "modified first-generation model" maintains this focus on the profit opportunities of speculators and the role of international reserves. For the Mexican case, these features were clearly important.

To capture other features of the Mexican experience, we have modified the standard first-generation model under uncertainty in several ways. We have not made the crisis inevitable by assuming ongoing monetization of the fiscal deficit. We have taken into account the monetary authority's practice of sterilizing the effects of reserve changes on the monetary base. We have also modeled price-setting behavior that allows the real exchange rate to appreciate and the domestic interest rate to rise in the period leading up to the attack and simplifies our treatment of the risk premium. Since the domestic interest rate depends on a time-varying stochastic risk premium as well as the conditional expected rate of change of the exchange rate, it may not rise much prior to an attack.

The time-varying stochastic risk premium introduces a nonlinearity into the asset markets. This nonlinearity gives rise to the possibility of self-fulfilling risk predictions *for some range of the fundamentals*. Multiple equilibria are generated solely by private sector behavior and do not require a change in government policy *ex post* to validate the attack. If private investors suddenly come to believe there is increased risk, that alone can lead to a self-fulfilling speculative attack if the economy's fundamentals have deteriorated sufficiently. While

[22] See e.g. Jeanne's (1997) empirical tests for multiple equilibria related to the 1992-93 European crises.

the risk-premium channel need not be the only source of nonlinearities, it is a sensible and convenient way to focus on self-fulfilling speculative attacks arising solely from private-sector behavior.

### Derivation of the Risk Premium

The risk premium is calculated from the perspective of the foreign investor. The foreign investor holds the mix of domestic and foreign bonds that maximizes expected welfare, which depends positively on future real wealth and negatively on the variance of future real wealth relative to current wealth. The foreign investor's problem is:

$$Max_B \; E_t\{[W^*_{t+1}/\, P^*_{t+1}] - \frac{gV_t[W^*_{t+1}/P^*_{t+1}]}{[W^*_t/P^*_t]}\} \qquad \textbf{(A1)}$$

subject to the constraint

$$W^*_t = B^*_t + X_t B_t \qquad \textbf{(A2)}$$

where upper-case letters are levels, * signifies the assets are foreign-currency denominated (the foreign currency is the investor's own currency), $X_t$ is the exchange rate quoted as foreign currency/domestic currency, and g is a measure of risk aversion. Prices are set a period in advance in the foreign investor's currency.

The optimization yields the following risk premium on domestic bonds before linearization:

$$\frac{2g(1+i_t)^2 V_t(\frac{X_{t+1}}{X_t})X_t B_t}{(1+\pi^*_t)W^*_t} \qquad \textbf{(A3)}$$

We adopt the following linearizations/conventions:

$$z' = 2g(1+\bar{i})^2 \;/\; (1+\bar{\pi}^*)$$

$$V_t(\frac{X_{t+1)}}{X_t}) = V_t(x_{t+1}) = V_t(s_{t+1}) \qquad \textbf{(A4)}$$

$$\frac{X_t B_t}{W^*_t} = a_0 + a_1(b_t - b^*_t - s_t) = a_1(c + b_t - b^*_t - s_t)$$

where lower-case letters b, b*, x and s are logs, the average domestic interest rate $\bar{i}$ and the average foreign inflation rate $\bar{\pi}^*$ are taken as constants in the linearization, $s_t$ is the log exchange rate quoted as domestic currency/foreign currency, the coefficient $a_1$ is the share of domestic bonds in foreign wealth, and c is a constant equal to $a_0/a_1$. In the text, $\theta_t = zV_t(s_{t+1})$, where $z = a_1 z'$. Agents residing in the domestic and foreign countries are assumed to hold proportionately identical portfolios.

**The Shadow Exchange Rate**

We describe here our solution technique for obtaining the shadow exchange rate. Because prices are set a period in advance, the shadow rate at attack time t, $\tilde{s}_t$, is not the same as the flexible exchange rate in the following period, $\tilde{s}_{(t+1)}$. Since we need an expression for the expected depreciation of the exchange rate between time t and time t+1 to solve for $\tilde{s}_t$, we also must also solve for $\tilde{s}_{t+1}$.

Let the shadow exchange rate at time t and the flexible exchange rate at time t+1 take the forms:

$$\tilde{s}_t = \lambda_O + \lambda_1 h_{t-1} + \lambda_2 \varepsilon_t \qquad \textbf{(A5)}$$

$$\tilde{s}_{t+1} = \beta_0 + \beta_1 h_t + \beta_2 \varepsilon_{t+1} \qquad \textbf{(A6)}$$

The flexible exchange rate $\tilde{s}_{t+1}$ equilibrates the post-attack money market:

$$m_{t+1} - p_{t+1} = -\alpha[i^* + E_{t+1}(\tilde{s}_{t+2} - \tilde{s}_{t+1}) + \theta_{t+1}(c + b_{t+1} - b^* - s_{t+1})] + \delta\varepsilon_{t+1} \qquad \textbf{(A7)}$$

Three observations about (A7) are in order. First, since the monetary authority's policy is to keep the high-powered money base constant at all times, $m_{t+1} = \bar{m}$ in (A7).

Second, to obtain the expression for $b_{t+1}$ in (A7), we recall the log-linearization of the bond market.

$$b_{t+1} = \gamma h_{t+1} + (1-\gamma)d_{t+1}; \qquad \gamma > 1 \qquad \textbf{(A8)}$$

where private holdings of domestic-currency bonds (b) are equal to the total supply (h) net of the holdings of the domestic monetary authority (d). Post attack, the domestic bonds held by the central bank equal the high-powered money base since the central bank's international reserve holdings are completely depleted. Hence $d_{t+1}=m_{t+1}=\bar{m}$ and (A8) becomes:

$$b_{t+1} = \gamma h_{t+1}+(1-\gamma)\bar{m}. \tag{A9}$$

Third, b* is treated as a constant in (A7) on the assumption that central bank sales of foreign securities to agents speculating against the domestic currency are small relative to the worldwide holdings of these securities.

Given the assumptions above, the assumption that $p_{t+1}$ is set at a value expected to clear next period's goods market ($p_{t+1}=E_t\tilde{s}_{t+1}$), and the process specified for $h_{t+1}$ in the text, we substitute (A6) and (A9) into (A7) and solve for the shadow rate $\tilde{s}_{t+1}$ using the method of undetermined coefficients.

The solution for $\tilde{s}_{t+1}$ has the following coefficients:

$$\beta_0=\frac{\bar{m}[1+\alpha\theta_t(1-\gamma)]+\alpha i**+\alpha\mu\beta_1+\alpha\theta_t[c+\gamma\mu-b*]}{(1+\alpha\theta_t)}$$

$$\beta_1=\frac{\alpha\gamma\rho\theta_t}{[1+\alpha(1+\theta_t)-\alpha\rho]}\geq 0 \tag{A10}$$

$$\beta_2=\frac{\alpha\beta_1+\alpha\theta_t\gamma-\delta}{\alpha(1+\theta_t)}$$

where $\theta_t=zV_t(s_{t+1})$. Since $V_t(s_{t+1})$ is the variance of the shadow rate at time t+1 if there is a speculative attack at time t,

$$V_t(s_{t+1})=E_t(\tilde{s}_{t+1}-E_t\tilde{s}_{t+1})^2=\beta_2^2\sigma_\varepsilon^2 \tag{A11}$$

so that $\theta_t\equiv z\beta_2^2\sigma_2^2$. For later reference, note that in (A11), $\sigma_\varepsilon^2$ is the variance of the stochastic element $\epsilon$ that has a uniform distribution centered on zero with the range [-w,w]. Thus

$$\sigma_\varepsilon^2 = \int_{-w}^{w}\frac{1}{2w}(\varepsilon)^2 d\varepsilon = \frac{w^2}{3}. \tag{A12}$$

Letting $\theta_t \equiv z\beta_2^2\sigma_2^2$ in (A10) and manipulating terms, we find that $\beta_2$ satisfies the fifth-order polynomial:

$$c_0 + c_1\beta_2 + c_2\beta_2^2 + c_3\beta_2^3 + c_4\beta_2^4 + c_5\beta_2^5 = 0 \tag{A13}$$

where

$$c_0 = \delta[1 + \frac{1}{\alpha} - \rho]$$

$$c_1 = 1 + \alpha(1-\rho)$$

$$c_2 = -z\sigma_\varepsilon^2[\gamma\{1+\alpha(1-\rho)\} - \delta + \alpha\gamma\rho]$$

$$c_3 = z\sigma_\varepsilon^2[1+\alpha+\alpha(1-\rho)]$$

$$c_4 = -\gamma\alpha z^2(\sigma_\varepsilon^2)^2$$

$$c_5 = \alpha z^2(\sigma_\varepsilon^2)^2$$

For each of the five possible values of $\beta_2$, there is a corresponding value for $\beta_1$ and $\beta_0$ in (A10). Examing the $c_i$, we note that if the money-demand parameter $\delta$ equals zero, then $c_o = 0$ and one value for $\beta_2$ is zero. When $\beta_2 = 0$, $\theta = 0$ and $\beta_1 = 0$, so one solution for $\tilde{s}_{t+1}$ is deterministic. We call this solution the "market fundamentals" solution.

We are now ready to solve the model for $\tilde{s}_t$ the shadow rate at attack time t. The shadow rate $\tilde{s}_t$ equilibrates the money market at times t:

$$\bar{m} - p_t = -\alpha[i* + E_t(\tilde{s}_{t+1} - \tilde{s}_t) + \theta_t(c + b_t - b* - s_t)] + \delta\varepsilon_t \tag{A14}$$

where

$$p_t = E_{t-1}s_t = (1 - \pi_{t-1})\bar{s} + \pi_{t-1}E_{t-1}(\tilde{s}_t | \tilde{s}_t > \bar{s}) \tag{A15}$$

using equations (3) and (5) in the text.

We linearize the last term in (A15) as follows:

$$\pi_{t-1}E_{t-1}(\tilde{s}_t|\tilde{s}_t>\bar{s}) = -\bar{\pi}\hat{s} + \bar{\pi}E_{t-1}(\tilde{s}_t|\tilde{s}_t>\bar{s}) + \hat{s}\pi_{t-1}, \tag{A16}$$

where $\bar{\pi}$ is the average probability of attack next period and $\hat{s}$ is the average expectation of next period's exchange rate, conditional on an attack next period. We obtain an expression for $\pi_{t-1}$ in terms of the state. Recall that $\pi_{t-1}$ is the probability of an attack in period t based on time t-1 information:

$$\pi_{t-1} = pr\{\ \tilde{s}_t - \bar{s} > 0\} \tag{A17}$$

Given the expression for the shadow exchange rate in (A5), (A17) can be rewritten as:

$$\begin{aligned}\pi_{t-1} &= pr\{\lambda_O + \lambda_1 h_{t-1} + \lambda_2 \varepsilon_t - \bar{s} > 0\} \\ &= pr\{e_t > k_{t+1}\}\end{aligned} \tag{A18}$$

where $k_{t-1} = (\bar{s}-(\lambda_O + \lambda_1 h_{t-1})/\lambda_2 > 0$.

Since the shock is assumed to have a uniform distribution (-w, w) centered on zero,

$$\pi_{t-1} = pr\{\varepsilon_t > k_{t-1}\} = (w - k_{t-1})/2w. \tag{A19}$$

Substituting into (A19) our expression for $k_{t-1}$ gives:

$$\pi_{t-1} = e_o + e_1 h_{t-1}, \tag{A20}$$

where $e_o = (w\lambda_2 + \lambda_0 - \bar{s}\ )/2w\lambda_2$ and $e_1 = \lambda_1/2w\lambda_2$.

Next we obtain an expression for $E_{t-1}(\tilde{s}_t \mid \tilde{s}_t > \bar{s})$ in (A15). Given the proposed form for the shadow rate in (A5), $E_{t-1}(\tilde{s}_t \mid \tilde{s}_t > \bar{s}) = \lambda_o + \lambda_1 h_{t-1} + \lambda_2(E_{t-1}\varepsilon_t|\tilde{s}_t > \bar{s}\ )$. Since the distribution of $\varepsilon_t$ is uniform, the time t-1 expected value of the shock at time t, conditional on being in the post-attack regime at t, is

$$E_{t-1}(\varepsilon_t \mid \tilde{s}_t > \bar{s}) = k_{t-1} + (w - k_{t-1})/2. \tag{A21}$$

Substituting into (A21) the expression for $k_{t-1}$ yields:

$$E_{t-1}(\varepsilon_t \mid \tilde{s}_t > \bar{s}) = f_o + f_1 h_{t-1} \tag{A22}$$

where $f_o = (\bar{s} - \lambda_o + w\lambda_2)/2\lambda_2$ *and* $f_1 = -\lambda_1/2\lambda_2$.

Finally, we use (A5) and (A6) to derive an expression for the expected depreciation of the exchange rate between time t and time t+1 if there is an attack at time t:

$$E_t(\tilde{s}_{t+1} - \tilde{s}_t) = \beta_0 + \beta_1(\mu + \rho h_{t-1} + \varepsilon_t) - (\lambda_0 + \lambda_1 h_{t-1} + \lambda_2 \varepsilon_t) \tag{A23}$$

where the $\beta_i$ are given in (A10).

Substituting (A5), (A15), (A16), (A20), (A22) and (A23) into (A14), we solve for $\tilde{s}_t$ using the methods of undetermined coefficients. The shadow rate solution is described in the text by equations (7) - (10), where the actual expression for the constant terms in (8) is

$$\begin{aligned}\lambda_0 = {} & [\alpha(1+\theta) + \frac{\bar{\pi}}{2} + \frac{1}{4}]^{-1}\{\bar{m} + \frac{\bar{\pi}\bar{s}}{2} - \frac{3}{4}\bar{s} - \frac{\lambda_2 w}{4} + ai*+ \\ & \alpha\theta_t[c + \gamma\mu + (1-\gamma)\bar{m} - b^*] + \alpha\beta_0 + \alpha\beta_1\mu\}\end{aligned} \tag{A24}$$

The $\lambda_i$ coefficients reflect the fact that $\hat{s} = \bar{s} + \frac{\lambda_2 w}{2}$, where $\hat{s}$ is the expected value of the shadow rate conditional on having a shock large enough to put the economy into the attack range.

In the numerical example in the text, we take advantage of the information in (A10) - (A13) and set the average probability of an attack at $\bar{\pi} = 0.5$ since the economy is considered to be in the attack range.

Figure 1. Tabletop Picture of Shadow Rates Crossing Fixed Rate

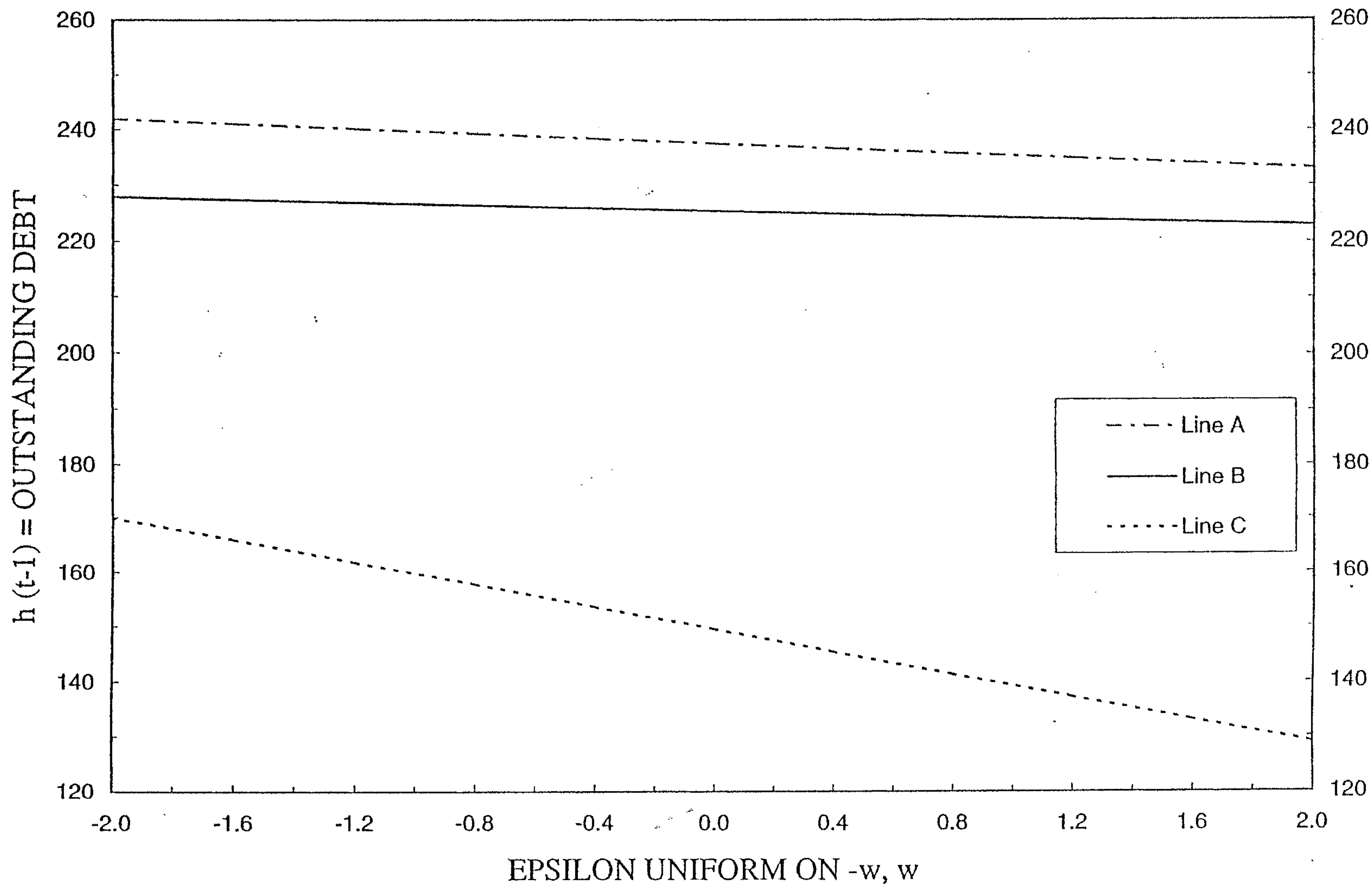
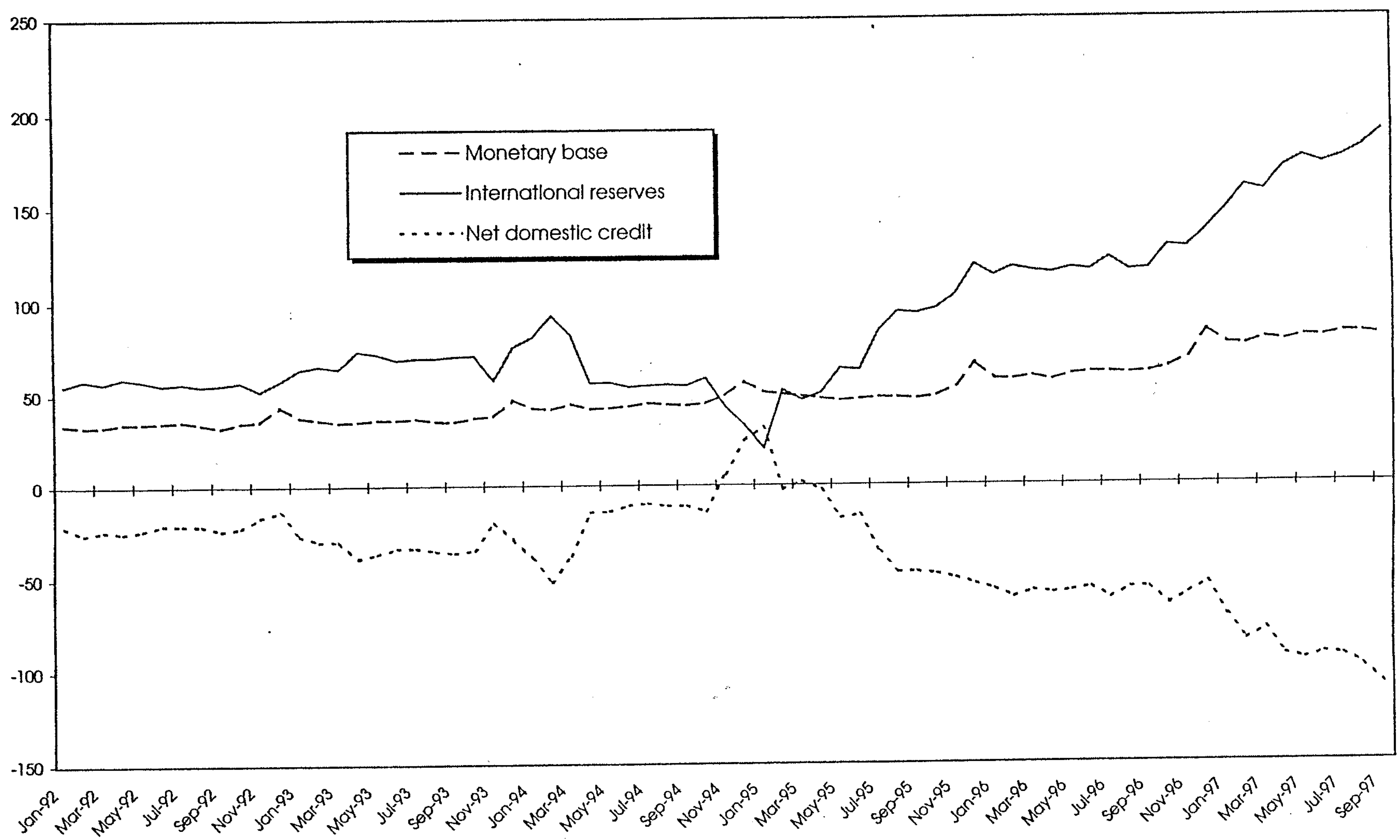


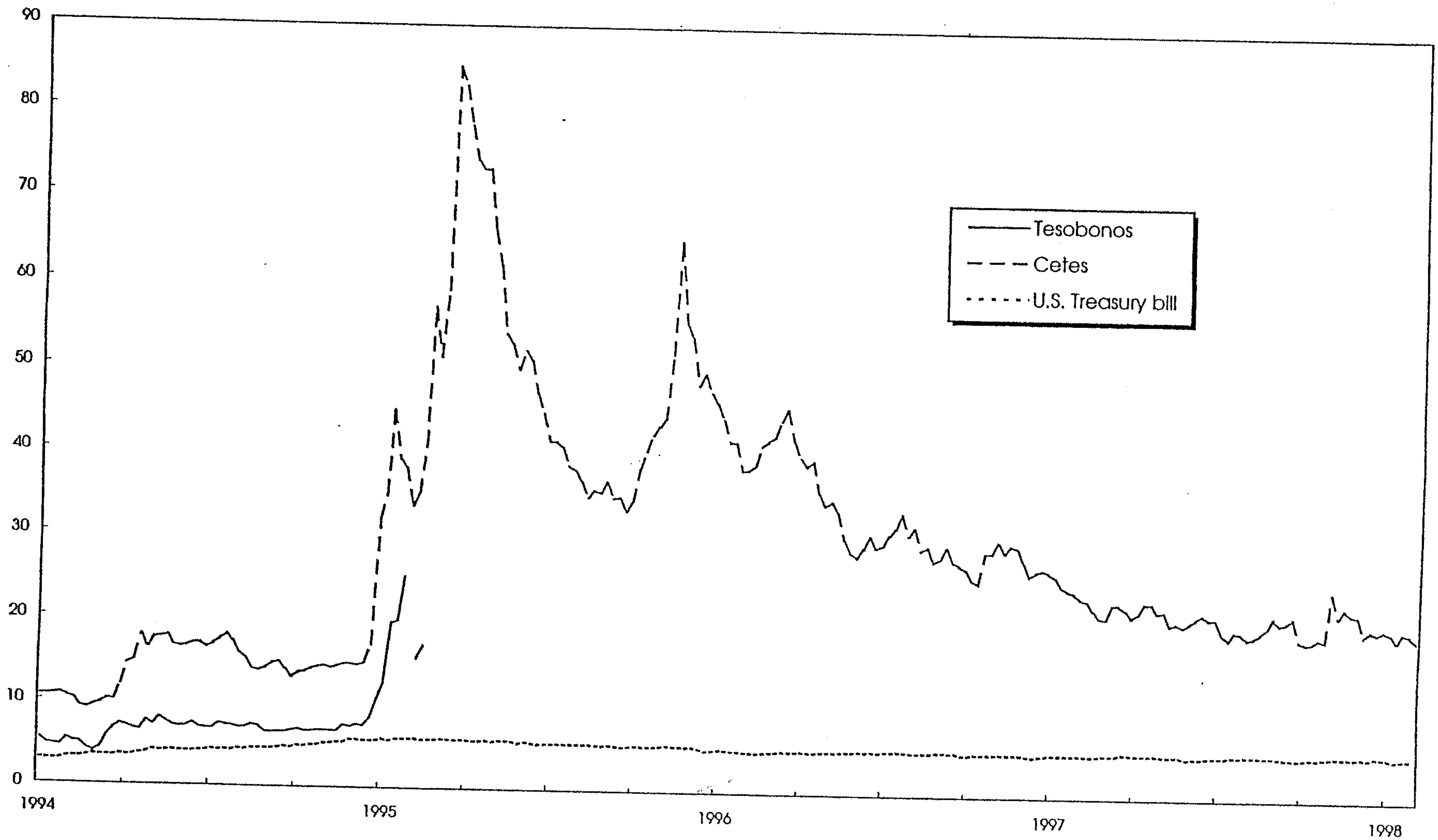
Figure 2. Mexico: Base Money by Component, January 1992-September 1997
(In billions of new pesos)




Source: Banco de Mexico, Indicadores Economicos (February 1995 and October 1997).

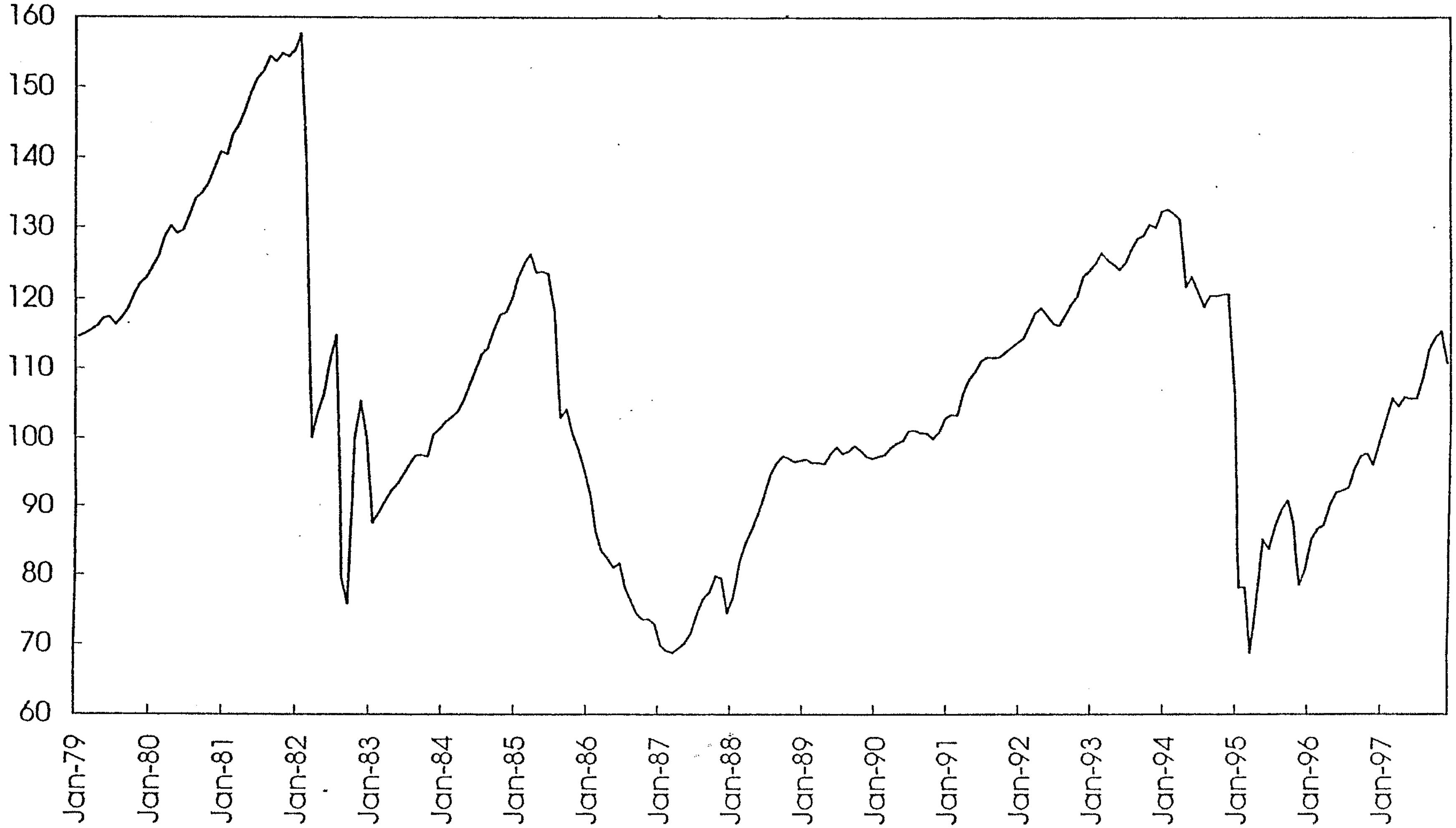
Figure 3. Yields on Mexican and U.S. Government Securities, January 1994-January 1997

(In percent)



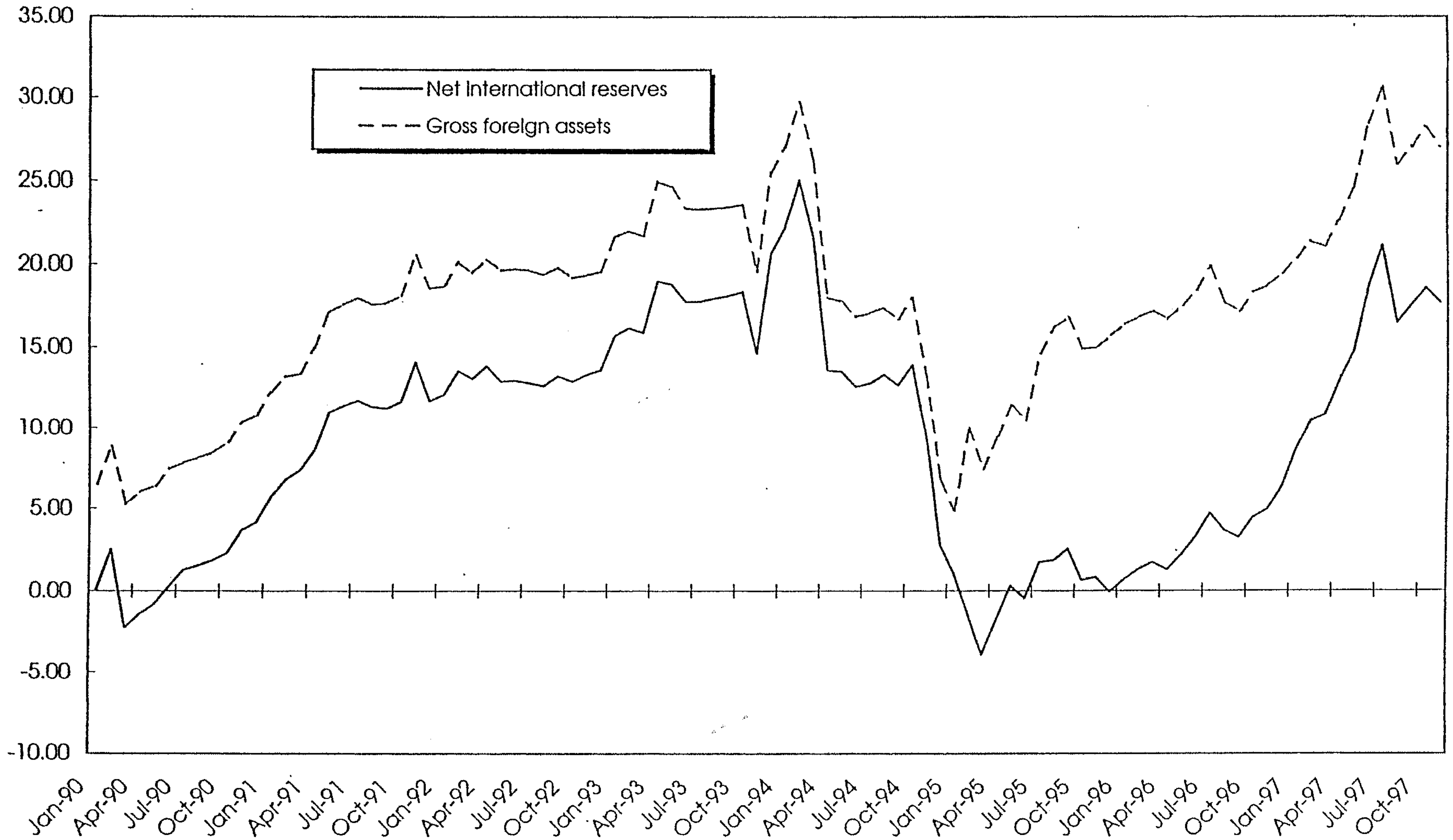

Source: Bloomberg Financial Markets L.P.

Figure 4. Mexico: Real Effective Exchange Rate,
January 1979-November 1997
(1990=100)




Source: International Monetary Fund.

Figure 5. Mexico: International Reserves,
January 1990-October 1997
(In billions of U.S. dollars)




Source: Banco de Mexico.

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