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Speculative Attacks and Currency Crises: The Mexican Experience

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Abstract

This paper estimates a speculative attack model of currency crises in order to identify the role of economic fundamentals and any early warning signals of a potential currency crisis. The data from the Mexican economy was used to illustrate the model. Based on the results, a deterioration in fundamentals appears to have generated high one-step-ahead probabilities for the regime changes during the sample period 1982-1994. Particularly, increases in inflation differentials, appreciations of the real exchange rate, foreign reserve losses, expansionary monetary and fiscal policies, and increases in the share of short-term foreign currency debt appear to have contributed to the market pressures and regime changes in that period.

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Contents

Summary

This paper examines the changes in Mexico's exchange rate regime during 1982-94 in an attempt to identify warning signals of a potential currency crisis and the role of macroeconomic fundamentals. To identify this role, the paper computes the probabilities for these regime changes as a function of economic fundamentals by using a model based on speculative attack literature, which underscores factors causing changes in reserves and the importance of the level of reserves. The paper notes that although the Mexican crisis at the end of 1994 and the subsequent turbulence in the foreign exchange markets were unprecedented, Mexico's exchange rate history indicates that the country has often experienced setbacks, reflecting fundamental factors, in its efforts to stabilize permanently its economy by using a pegged exchange rate regime.

The empirical findings indicate that, in general, the deterioration in economic fundamentals generates high one-step-ahead probabilities for the regime changes that took place in Mexico during the sample period. In particular, the periodic increases in inflation differentials vis-à-vis the United States, appreciations of the real exchange rate, sharp losses of foreign reserves, and expansionary monetary and fiscal policies appear to have contributed to the regime changes during that period. The paper also suggests that the rise in private indebtedness, rather than in public imbalances, was partly responsible for the most recent financial crisis in Mexico. The sharp losses of foreign reserves appear to have been crucial in shaping the authorities' decision to abandon the crawling band regime in 1994, and the inclusion of the share of shorter-term foreign-currency-indexed debt improves the model's fit.

The recent Mexican experience also confirms that the sustainability of exchange rate policy depends crucially on adequate policy responses to shocks to the economy and on the extent of fragility of the economic and financial system. The Mexican experience illustrates that regardless of significant progress in economic performance, free capital flows leave little room for divergence between an "equilibrium" exchange rate and a peg.

I. Introduction

Following periods of turbulence amidst political and economic uncertainties during 1994, the Mexican authorities announced a 15 percent devaluation of the Mexican new peso on December 20, 1994. Continued selling pressures on the currency forced the authorities to withdraw support in foreign exchange markets as foreign reserves of the Bank of Mexico fell, and to abandon on December 22, 1994 the crawling band exchange rate mechanism, which had been in effect since November 1991. While Mexico's success since 1987 in reducing inflation to single digit levels, maintaining a moderate pace of economic growth, and containing the fiscal deficit (the operational fiscal balance was in surplus since 1990) created market views that the fundamentals of the Mexican economy had been improving, several other factors remained as sources of concern. In particular, a marked real appreciation of the currency since 1991--in part reflecting the significant increase in capital inflows--contributed to a widening of the trade and current account deficits; 1/ the continuation of domestic political tensions raised questions concerning the credibility of the future of economic policy; furthermore, the foreign reserves of the central bank, crucial to a fixed exchange rate system, had declined in steps from its peak level of $29 billion in early 1994 to about $12 billion in November. 2/

While the severity of the Mexican financial crisis in 1994 was unprecedented, Mexico's history on exchange rate policy has been characterized by periods of a fixed exchange rate or managed float regime, alternated with brief periods of floating rate systems following episodes of balance of payments crises. The purpose of this paper is to estimate the factors contributing to the changes in Mexico's exchange rate regime over the period 1982-94, in order to evaluate whether the speculative pressures and the associated regime changes in this period were brought about by a deterioration in Mexico's economic fundamentals. A better understanding of the origins of the Mexican crises may help identify early warning signs and suggest policy options for countries in similar situations.

The literature on balance of payments crises provides a theoretical framework to analyze currency crises in the context of a small open economy with a fixed exchange rate system. That framework attempts to capture a systematic relationship between foreign exchange crises and macroeconomic fundamentals. In its simplest form, as first formalized by Krugman (1979),

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1/ In particular, the acceleration in the size of the current account deficit (from a balanced position in the late 1980s to about 8 percent of GDP in 1994), as well as its composition (driven mainly by consumption), were important factors in leading to the crisis.

2/ On October 1, 1994 former Mexican President Carlos Salinas announced in his state of the nation address that central bank reserves had fallen to US$17 billion from US$28 billion at the end of 1993. (See The Washington Post, February 13, 1995.) However, foreign reserves remained at a stable level from the end of April until mid-November in 1994.

the speculative attack model outlines a process in which fiscal imbalances lead to an eventual collapse of a peg regime. Such imbalances generate domestic credit expansions that cause a gradual erosion of foreign exchange reserves. The latter is followed by generally self-fulfilling speculative attacks on the currency, as forward-looking investors engage in one-sided bets in anticipation that reserves will not be sufficient to defend the peg. As reserves reach a critical level, the fixed exchange rate can no longer be sustained and the prevailing regime collapses. The collapse involves either a discrete devaluation or a switch to a flexible exchange rate regime, under which the currency sharply depreciates.

In order to help identify the contribution of economic fundamentals to Mexico's foreign exchange crises, this paper computes the probability of a regime change as a function of economic fundamentals by using the implications of the speculative attack literature. Even though the model, by nature, simplifies some aspects of a complex phenomenon, the results overall suggest that a deterioration in some of Mexico's economic fundamentals are statistically significant factors of the observed exchange rate regime changes in the sample period 1982-94. Among these fundamentals, periodic expansions in domestic credit, a widening of fiscal deficits, a deterioration in external competitiveness, and increased inflation differentials vis-à-vis the United States appear to have increased the probability of the observed regime changes. In addition, it appears that falls in foreign reserves also significantly contributed to increases in the probability by undermining the ability of the central bank to defend its peg. Furthermore, the results and the predictive power of the model appear to be sensitive to the timeliness of information, underscoring the importance of data availability for obtaining early warning signals of possible upcoming crises.

The results also indicate that the recent Mexican financial crisis was not the result of fiscal imbalances; rather, it was the rise in private sector indebtedness and the corresponding increase in credit to the banking system that augmented the pressures building up in the exchange market in mid-1994. In that respect, it is important to note that the unfolding of events in Mexico leading to the recent crisis followed a course different from that suggested in the speculative attack literature. In this literature, domestic credit expansion leads to reserve losses that culminate in the crisis, while in Mexico it was the domestic political tensions during 1994 that triggered the initial reserve losses. During the period 1989-92, the combined effects of lower inflation, financial sector reform, fiscal adjustment, and less-than-full sterilization of capital flows had led to a sharp rise in financial deepening in Mexico, and had eased the private sector's access to credit. Nevertheless, the expansionary effect of this rise in private sector credit had been largely offset by the decline in credit to the public sector--thanks to an improved fiscal position. Furthermore, the surge in private capital inflows had resulted in a marked strengthening of the reserves position, which the authorities had sterilized by reducing net domestic credit in the period from March 1990 to March 1994 in order to dampen the inflationary impact of the capital flows.

In the remaining part of 1994, however, after a temporary period of tight credit conditions, the authorities attempted to sterilize the foreign reserve losses stemming from increasing political and economic uncertainties by providing credit to the banking system 1/ and by converting short-term peso-denominated government liabilities (cetes) falling due to dollar-denominated bonds (tesobonos). The move aimed at keeping the monetary base stable and preventing a sharp hike in domestic interest rates, which were viewed as creating difficulties for the financial sector. 2/ With the benefit of hindsight, it appears that this strategy proved ineffective in an environment with vast volumes of free capital movements and a large current account deficit, as political tensions that were believed to be temporary shocks to the system continued, and as the authorities attempted to keep the monetary base stable. 3/ In summary, the deterioration in Mexico's economic fundamentals helps explain the financial crisis of end 1994, though the unexpected political and external shocks during 1994 played an unambiguous triggering role.

The paper is organized as follows. Section II provides a brief review of the literature on currency crises. Section III presents an overview of the exchange rate developments in Mexico. Sections IV and V outline the model and the estimation procedure, respectively. Section VI presents the empirical results, while section VII addresses some further empirical considerations. Finally, some concluding remarks are provided in section VIII. Appendix I provides data sources, and Appendix II presents some specification tests for the models used in the paper.

II. A Brief Review of Literature on Currency Crises

The speculative attack literature on currency crises in the context of a small open economy with a fixed exchange rate regime has built on a model suggested by Krugman (1979). Survey articles on speculative currency crises by Agénor, Bhandari, and Flood (1992) and Blackburn and Sola (1993) provide a detailed description of these extensions to the basic currency crisis model.

Empirical tests of the currency crisis model have been provided in the context of several Latin American currencies and the currencies of some

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1/ Between February and August 1994 total central bank credit to deposit money banks and development banks rose from about MexN$4.5 billion to MexN$20 billion.

2/ The monetary base remained roughly constant during that period, while the decline in reserves matched the increase in net central bank credit (The Bank of Mexico (1995)).

3/ See also "Drawing Lessons from the Mexican Crisis: Preventing and Resolving Financial Crises--the Role of the IMF," address by Michel Camdessus, May 22, 1995; IMF, World Economic Outlook, Annex I, May 1995; and Sachs, Tornell, and Velasko (1995).

industrial countries, and have found empirical support for the basic currency crisis model. In particular, Blanco and Garber (1986) produce estimates of one-period-ahead probabilities of devaluation and the expected value of the new fixed exchange rate for the Mexican peso in the 1973-82 period. Their model replicates some aspects of the Mexican financial history, and the computed probabilities of devaluation reach relatively high values prior to actual devaluations. Similarly, Goldberg (1994) calculates ex-ante probabilities of currency crises and attempts to predict the sizes of expected devaluations of the Mexican peso for the period between 1980 and 1986. She finds that domestic fiscal and monetary shocks were the main forces contributing to speculative attacks on the Mexican peso. Using Argentina's experience with a crawling peg system between December 1978 and February 1981, Cumby and van Wijnbergen (1989) find results suggesting that the viability of an exchange rate regime depends on the consistency of exchange rate policy with domestic credit policy.

In the context of developed countries, Grilli (1990) applies the speculative attack model to the episode of foreign exchange market pressure on the U.S. dollar in the period 1894-1896, when the gold standard was in effect. Edin and Vredin (1993) formulate and estimate a model of devaluations within target zones in Nordic countries for the period 1978-1989 by relating devaluations to economic fundamentals. Ötker and Pazarbaşıoğlu (1994) apply the speculative attack model and the target zone approach to European currency crises experienced in the 1979-93 period. For a sample of five European currencies, they empirically show that economic fundamentals as well as speculative factors had a significant role in the observed exchange rate regime changes.

III. Mexico: An Overview of Exchange Rate Developments (1980-94)

The exchange rate has played an important role in Mexican economic policy, and has had a central role in its anti-inflation strategy since 1988. Mexico's history provides examples of a number of exchange rate regimes, reflecting, among other things, the country's particular economic objectives and the specific economic conditions it faced. In particular, Mexico adopted many different forms of a pegged exchange rate system--ranging from a pure peg to the U.S. dollar to a crawling band system--alternated with brief periods of floating exchange rate regimes following episodes of balance of payments crises (Table 1).

Following a period of fixed exchange rates from the mid-1950s to the mid-1970s and a large devaluation of the peso (about 38 percent) in 1976, Mexico adopted a "fixed but adjustable" exchange rate system until the early 1980s. Balance of payments problems in early 1981--with the currency sharply appreciating in real terms and the fiscal deficit and external debt increasing markedly--caused an acceleration of capital flight and led to a sharp depreciation of the currency against the dollar. The authorities responded to the crisis by a sharp devaluation of the official peso rate in

Table 1. Mexico: Exchange Rate Developments

Period	Exchange rate system	Policy changes	Comments
February 1982	Free floating exchange rate	Devaluation of the peso Subsequent switch to float	Devaluation = more than 75 percent in February
August 5, 1982	Fixed but adjustable exchange rates in a dual exchange rate system	Introduction of the dual exchange system	Exchange rate in the controlled market determined by the Bank of Mexico Exchange rate in the free market determined by commercial banks
December 20, 1982	Preannounced crawling peg	Introduction of a preannounced crawling peg against the dollar Establishment of exchange controls as part of the economic program	Value of the controlled exchange rate announced daily Rate of crawl: 13 cents per day
December 6, 1984	Preannounced crawling peg	An increase in the rate of crawl	Rate of crawl: 17 cents per day (32.2 percent annual implied depreciation)
March 6, 1985	Preannounced crawling peg	An increase in the rate of crawl	Rate of crawl: 21 cents per day (38.0 percent annual implied depreciation)
July 25, 1985	Preannounced crawling peg	Devaluation of the peso	Devaluation = 20 percent
August 5, 1985	Managed float	Abandonment of preannounced crawling peg; subsequent switch to managed floating in the controlled market	The value of the peso adjusted daily by unspecified amounts (effectively a crawling peg)
November 18, 1987	Free floating exchange rate	Withdrawal of Bank of Mexico support from the foreign exchange market	The flexible exchange rate depreciated 32.8 percent in one day Differential between preferential and flexible rate reached 35.1 percent
December 14, 1987	Free floating exchange rate	Devaluation of the peso	Devaluation = 21.8 percent
December 15, 1987	Preannounced fixed peg	Announcement of preannounced fixed peg	Fixed rate: MexN$2,209.7/US$
January 31, 1988	Preannounced fixed peg	Increase in preannounced fixed peg	Fixed rate: MexN$2,221/US$
February 1988	Preannounced crawling peg	Abandonment of preannounced fixed peg Switch to preannounced crawling peg Devaluation of the peso	Rate of crawl: 2 pesos per day Devaluation = 2.7 percent

Table 1 (Concluded). Mexico: Exchange Rate Developments

Period	Exchange rate system	Policy changes	Comments
March 1988	Fixed exchange rate system	The peso fixed against the U.S. dollar	Fixed rate: MexN$2,281/US$
January 1989	Preannounced crawling peg	Switch to preannounced crawling peg	Rate of crawl: 1 peso per day (1.3 percent per month, 16.5 percent annual implied depreciation)
May 27, 1990	Preannounced crawling peg	Reduction in the crawl rate	Rate of crawl: 80 cents per day
November 12, 1990	Preannounced crawling peg	Reduction in the crawl rate	Rate of crawl: 40 cents per day
November 11, 1991	Exchange rate intervention band	Abolition of dual exchange rate system and exchange controls Introduction of exchange rate bands	Band floor: fixed at MexN$3,051/US$ Band ceiling: depreciate daily against the U.S. dollar Rate of Crawl of the ceiling: 20 cent per day (2.36 percent per year) No official announcement of central rate, but daily announcement of the lower and upper bounds
October 21, 1992	Exchange rate intervention band	Increase of the crawl rate of the upper band	Band floor: fixed at MexN$3,051/U.S$ Band ceiling: depreciate daily against the U.S. dollar Rate of Crawl of the ceiling: 40 cent per day (4.63 percent per year)
January 1, 1993	Exchange rate intervention band	Introduction of new peso	MexN$1 = MexN$1,000
December 20, 1994	Exchange rate intervention band	Devaluation of the new peso's band ceiling	Devaluation = 15 percent Exchange rate rose from MexN$3.46/US$ to MexN$3.99/US$
December 22, 1994	Free floating exchange rate	Abolition of intervention bands and Switch to free floating	Peso depreciated by 71 percent for 1994 as a whole

Source: Mexican Authorities; Mexico--Recent Economic Developments, various years; Reichman (1992).

February 1982, but subsequently let the currency float as capital continued to flow out. In June 1982, the peso was put on a controlled (managed) float but, following persistent selling pressure on the currency, the authorities again withdrew support for the peso.

The authorities subsequently introduced exchange controls and a dual exchange rate system; the latter consisted of an "official rate," which was determined by the Bank of Mexico in terms of a preannounced crawling peg, 1/ and a "free rate," which was determined by commercial banks and with which the official rate was expected to converge. 2/ The system remained in effect from December 1982 to mid-1985, and the peso in the controlled market depreciated daily against the U.S. dollar by small predetermined amounts, with the rate of crawl increased twice, in 1984 and 1985. The preannounced crawling peg was reintroduced in January 1989 and remained in effect until November 1991, with the rate of crawl adjusted downward twice, in May and November 1990. In the interim period, the peso was subject to managed floating and to free floating as the currency came under speculative pressure reflecting economic imbalances, and was subsequently fixed against the dollar between end-1987 and end-1988, as the authorities focused on the need to stop inflation, which was running at triple-digit levels.

A significant real appreciation of the currency during a period of first fixed and then small adjustments in the exchange rate induced the authorities to introduce a more flexible exchange rate policy to compensate for the prevailing loss of competitiveness and to deal with capital inflows. In November 1991, the authorities unified the exchange system and introduced a crawling intervention band. The adoption of the intervention band was perceived as a way to resolve the fundamental short-run policy trade-off between the level of the real exchange rate and the level and variability of the nominal exchange rate (the rate of inflation). On the one hand, the authorities used exchange rate realignments to compensate for persistent inflation differentials to preserve and improve the current account

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1/ A preannounced crawling peg is a system in which the monetary authority fixes a preannounced path of the exchange rate and implements changes in par values progressively and predictably. Furthermore, occasional discrete devaluations are allowed to compensate for any excessive losses in competitiveness. The regime can be viewed as an adaptation of the fixed exchange rate system to an economy in which the rate of inflation considerably exceeds that of partner countries. This policy can serve to reduce expectations of inflation to eventually bring down inflation to comparable levels with the trading partners, while maintaining, at the same time, the competitiveness of the country's exports.

2/ The controlled market rate applied to most export and import payments receipts and was estimated to account for about 75 percent of foreign exchange transactions. The free market rate applied to most service receipts and payments and any prepayments of outstanding private debt obligations.

position; on the other hand, they recognized that frequent exchange rate depreciations could weaken the role of the exchange rate as a nominal anchor and could fuel inflationary expectations.

The floor of the intervention band (the peso's "strongest" or "most appreciated" level) was fixed at the prevailing exchange rate of Mex$3,051 per U.S. dollar, while the ceiling of the band (the peso's "weakest" or most depreciated" level) was set to depreciate daily by specified nominal amounts, thereby creating a gradually widening band within which the value of the peso could fluctuate freely. The authorities announced officially the band's crawling upper and fixed lower limits, its width, and their narrow band target range for each trading day. The Bank of Mexico conducted extensive intra-marginal intervention which kept the exchange rate within an inner band narrower than the official band 1/ until the beginning of 1994.

With a continuous crawling of the upper band, the width of the band increased from 1.2 percent in November 1991 to about 14 percent toward end-1994. The "new peso," introduced in January 1993 and equal to 1,000 "old pesos," traded close to the floor of its fluctuation band until the end of 1993, but came under pressure in November 1993 in light of uncertainties regarding NAFTA, and later in 1994. The new peso hit the ceiling of its band and traded mostly close to the ceiling in the rest of that year, reflecting a combination of political, economic, and external factors. The authorities announced a 15 percent devaluation of the ceiling of the band on December 20, as, inter alia, the margin for exchange rate adjustments within the band eroded, the level of international reserves had fallen significantly, and real interest rates had reached high levels, causing difficulties for financial intermediaries and debtors in general. 2/ Continued selling pressures caused the authorities to abandon the crawling band regime on December 22, 1994, with a resulting sharp depreciation of the exchange rate and a sharp rise in domestic interest rates.

IV. The Model

In order to evaluate the influence of macroeconomic fundamentals on exchange market pressures for the Mexican peso, this paper uses an extension of the basic speculative attack model developed by Flood and Garber (1984). The speculative attack model is a stochastic version of the monetary approach to exchange rate determination, in which the government and monetary authority of a small open economy are committed to maintaining the exchange rate within some form of a fixed exchange rate system. The

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1/ See Helpman, Leiderman, and Bufman (1994), p. 291.
2/ See "The Mexican Economy 1995," The Bank of Mexico, p. 43.

following equations describe the model:

$$m_t^d - p_t = \beta + \Omega y_t - \alpha i_t + w_t \tag{1}$$

$$m_t^s = \log(D_t + R_t) \tag{2}$$

$$i_t = i_t^* + Ee_{t+1} - e_t \tag{3}$$

$$p_t = p_t^* + e_t + u_t \tag{4}$$

$$m_t^d = m_t^s \tag{5}$$

where, m, p, y are the logarithms of the money stock, domestic price level, and real output, respectively, i is the domestic nominal interest rate, w is a stochastic disturbance to money demand, D is the domestic credit extended by the central bank, R is the foreign reserves of the central bank, i^* is the foreign nominal interest rate, p^* is the logarithm of the foreign price level, and e and u are the logarithms of the nominal and real exchange rates, respectively. The former, e, is defined as the units of the domestic currency required to buy a unit of the foreign currency, and a rise in e implies a depreciation of the domestic currency. Similarly, an increase in u implies a real appreciation of the currency. E represents the expectation conditional on information available in the current period. The subscripts d and s denote demand and supply, respectively.

Equation (1) specifies the transactions and asset motives for holding real money balances. Equation (2) defines base money as the sum of domestic credit extended by the central bank and the book value of the central bank's foreign reserves. Equation (3) is the interest parity condition, which states that the interest rate differential between the domestic and foreign country is given by the expected rate of depreciation of the currency. Equation (4) allows for deviations from purchasing power parity by the term, u_t, which denotes the real effective exchange rate. Finally, equation (5) gives the condition for money market equilibrium.

The money market equilibrium condition determines the path of foreign reserves of the central bank under a fixed exchange rate system. When reserves that are used to maintain this equilibrium are exhausted, or when

they reach a critical level, R_c, the exchange rate must adjust. 1/ The central bank must abandon the prevailing fixed exchange rate by either devaluing or allowing its currency to float. The floating exchange rate, $\tilde{e}_t$, which would clear the market when the central bank stops defending its fixed parity can be obtained by using equations (1)-(5). The path of the floating exchange rate is given by the following equations:

$$(1+\alpha)\,\tilde{e}_t - \alpha E\tilde{e}_{t+1} = h_t \ , \quad \textit{where} \tag{6}$$

$$h_t = \log(D_t + R_c) - \beta - \Omega y_t + \alpha i_t^* - p_t^* - u_t - w_t \ ) \tag{7}$$

The floating rate provides the lower bound for the new (i.e., the minimum necessary depreciated) value of the exchange rate after a devaluation or a switch to a flexible exchange regime. This new rate is referred to as the "shadow exchange rate," $\hat{e}$. 2/ As specified by equation (7), h_t represents the state of the economy as a function of economic fundamentals. Assuming that market fundamentals follow a first order autoregressive process and using the method of undetermined coefficients, equation (6) can be solved for the shadow exchange rate as a function of these fundamentals (see e.g., Flood and Garber (1984) and Goldberg (1991)):

$$\hat{e}_t = f\,(h_t) \tag{8}$$

where f is a non-linear function. Given the shadow exchange rate, the probability of a regime change can be approximated by that of a speculative attack: speculators decide to attack the central bank's foreign currency reserves if and only if the attack is expected to be profitable, i.e., if speculators operating in the current period expect the shadow rate to exceed the actual fixed rate. If speculative attacks deplete the bank's reserves to a critical level and thus cause the bank either to devalue or to float the currency, then speculators make a gross profit equal to the non-negative difference between the shadow and the prevailing actual fixed rates for each unit of reserves they purchase from the central bank. Formally, the one-step-ahead probability of a regime change, π_t, can be approximated by

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1/ The critical level of reserves could be zero, negative or positive. In perfect capital markets, the central bank can create foreign reserves by borrowing from international markets, which might result in a negative critical reserve level.

2/ The shadow exchange rate may be equal to or greater than the floating exchange rate, depending on the size of the disturbance to the fundamentals that forced the regime change.

computing the probability that the shadow exchange rate next period will exceed the prevailing fixed exchange rate, $\bar{e}$:

$$\pi_t = pr(\dot{e}_{t+1} > \bar{e}_t) = g(h_t, \bar{e}_t) \tag{9}$$

where g is a nonlinear function and h is defined as before. 1/ Equation (9) is used as a basis for the estimation of the probability of a regime change, which is expected to peak before or at the period in which the regime change materializes. Estimating the probability of devaluation in this manner attempts to capture the systematic relationship between the realized regime changes and economic fundamentals, and to evaluate whether speculative pressures on the currency can be accounted for by economic fundamentals.

V. Empirical Methodology

In order to test the implications of the model described in the previous section, first the country's decision regarding a change in its exchange rate regime is treated as a discrete variable, which takes on only two values: one, when there is a regime change--a discrete devaluation or a switch to more flexible rates--and zero when the existing regime is maintained. Then, the one-step-ahead probability of a regime change, π, is estimated as a function of a set of explanatory variables using a probit model, which is commonly used in estimation of models with qualitative dependent variables:

$$Prob(Y=1) = \Phi(X,\beta),$$
$$Prob(Y=0) = 1 - \Phi(X,\beta),$$

where, Y denotes the authorities' decision variable, "regime," X denotes a set of explanatory variables, β denotes the vector of parameters that reflect the impact of changes in X on the probability, and Φ denotes the cumulative normal distribution function. 2/

1/ $\bar{e}$ is the fixed value of the exchange rate under a pure peg exchange rate system, and equals some pre-announced or upper bound level (i.e., the most depreciated value to which the currency is allowed to fall) if the exchange rate regime is a crawling peg, a crawling band, or a target zone arrangement.

2/ Conventional estimation techniques are not appropriate in the analysis of models with a qualitative dependent variable since the variable can only take on a limited range of values. The estimated probability of a regime change can only take on values between zero and one. However, it is quite possible to have estimated probabilities outside the 0-1 range if conventional techniques are used. Using the cumulative normal function, the probit models yields estimated probabilities, which will by construction lie within the 0-1 range.

In the framework of this paper, the predicted value of the dependent variable can be interpreted as the probability that authorities will change the prevailing exchange rate regime. As implied by equations (7) and (9), the one-step-ahead probability of a regime change is then estimated as a function of fundamentals and the prevailing upper bound on the exchange rate. These fundamentals include the level of domestic credit from the central bank, real effective exchange rate, price level of the anchor country, foreign reserves, real output growth, and foreign nominal interest rate.

A rise in the level of domestic credit, which is not sterilized by central bank intervention, is expected to increase the probability of a regime change in the following period by increasing inflationary pressures through monetary expansion or through lower real interest rates. On the other hand, if the central bank sterilizes, foreign reserves will fall, reducing the ability of the central bank to defend its fixed parity and still inviting speculative attacks. In general, an expansion in domestic credit by the central bank reflects an increase in public or private sector indebtedness. Therefore, we use central bank claims on the banking system, D^b, or fiscal deficit, *Def*, as proxies for the government's expansionary policy stance. This specification also allows us to evaluate the relative importance of public sector and private sector indebtedness in leading to the observed regime changes.

An appreciation of the real exchange rate might signal a loss of international competitiveness, increasing expectations of an exchange rate adjustment as the appreciation is expected to worsen the current account balance. An extension of the basic currency crisis model, described in Agénor et al. (1992), includes an equation in which net exports are assumed to be a decreasing function of the real exchange rate and the level of economic activity. The inclusion of the real exchange rate in the estimation accounts for this indirect effect. An alternative way to estimate the pressure on the exchange rate is to include the trade or current account balance, *CA*, directly.

The higher the critical level of reserves below which the central bank is unwilling to allow its reserves to fall, R_c, the higher is the probability of a regime change. This critical level is generally unknown to the public. Due to the difficulty in quantifying this reserve level, we instead use the actual level of reserves. This can be justified by the fact that periods prior to a currency crisis are often associated with a rapid loss of reserves as individuals hedge themselves against the exchange rate risk, reflecting the weakening of their confidence in the sustainability of the fixed parity. Rapidly falling reserves invite further speculative attacks as speculators doubt the ability of the central bank to defend its currency. Hence, the lower the level of foreign exchange reserves (or

higher the rate of fall), the higher is the probability of a future regime change. 1/

An increase in the price level of the anchor country, other things being constant, reduces inflation differentials and thus the probability of a devaluation. The impact of an increase in the level of domestic output (or an increase in its growth rate) on the probability of devaluation is, in general, ambiguous. On the one hand, a higher output level or its growth rate might signal stronger economic performance, increase the money demand, and reduce the probability of a regime change. On the other hand, it might also imply a higher propensity to import and might exert pressure on the currency through its adverse effect on the current account balance. Higher foreign interest rates, other things being constant, lead to higher foreign debt service and capital outflows by reducing the attractiveness of domestic financial assets, and thus exert pressure on the domestic currency. Finally, an increase in the prevailing upper bound on the exchange rate decreases the probability of a further devaluation.

Following the above discussion, the probability of a regime change in period t+1 can be written as,

$$\pi_t = g\left[D_t(D_t^b, Def_t),\ u_t\ (CA_t),\ R_t,\ i_t^*,\ y_t\ (\Delta y_t),\ P_t^*(\Delta P_t - \Delta P^*_t),\ \bar{e}_t\right] \quad (10)$$

where the variables in parentheses indicate the alternative variables used in the estimation process.

VI. Estimation Results

This section provides the findings from the estimation of equation (10) based on monthly data for the period 1982:10-1994:12. 2/3/ During this period the Mexican peso was devalued three times, the authorities undertook a switch to more flexible exchange rate regimes on four occasions, and simultaneously devalued and switched to a more flexible exchange rate system on two occasions. Furthermore, during the crawling peg periods, the authorities increased the rate of crawl of the peso on three occasions and also reduced the rate on two other occasions. In estimating the one-step

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1/ The actual reserve level, however, should not be interpreted as a proxy for the critical reserve level, since the movements in the two variables have opposite effects on the probability of a regime change.

2/ A note of caution is warranted as regards these findings. In general, these are conditional results based on historical data; their use in predicting future regime changes are subject to margins of error through the model specification.

3/ The probit model was estimated by using analytic first and second derivatives to obtain maximum likelihood estimates via the Newton-Raphson algorithm in TSP.

Table 2. Regime Changes used in the Estimations

Dates	Regime Changes
December 1982	Switch to preannounced crawling peg from fixed but adjustable exchange rates
July 1985	Devaluation of the peso
August 1985	Switch to managed floating from preannounced crawling peg
November 1987	Switch to free floating from managed floating
December 1987	Devaluation of the peso
January 1988	Increase in preannounced fixed peg (effective devaluation)
February 1988	Devaluation and switch to preannounced crawling peg from preannounced fixed peg
January 1989	Switch to preannounced crawling peg from fixed exchange rates
December 1994	Devaluation of the new peso and switch to free floating

Source: Table 1.

ahead probabilities, the regime variable was assigned the value of one on those occasions when either a discrete devaluation and/or a switch to a more flexible exchange rate system took place (Table 2). 1/ The regime variable was assigned the value of zero in all other cases. The results ofthe probit analysis and the corresponding estimated one-step-ahead devaluation probabilities are presented in Table 3 and Chart 1. 2/

The empirical findings suggest that the probability associated with all regime changes in the sample period can be attributed to speculative pressures in light of some deterioration in economic fundamentals. In line with expectations, the probability of devaluation was found to be increasing in the level of the central bank credit to the banking system (or, alternatively fiscal deficit), the inflation differential vis-à-vis the United States, the loss of foreign exchange reserves and competitiveness--as measured by an appreciation of the real exchange rate--, and decreasing in the upper bound on the exchange rate. 3/ The sign of real output growth turned out to be positive, perhaps reflecting that external balance considerations dominated the traditional money demand argument.

In addition, it appears that there is no support for claims that increases in U.S. interest rates played an important role in the regime changes that took place in Mexico. For the first two specifications in Table 3, i.e., when credit to the banking system is used as the proxy for expansionary policy, a negative, though insignificant, relationship is found between U.S. money market rates and the probability of a regime change. 4/ Furthermore, the magnitude of the negative sign of the coefficient for the interest rate variable increases when the fiscal deficit is used as the proxy variable for expansionary policies. This negative relationship between the probability and the interest rate is partly due to the contemporaneous correlation between the U.S. interest rate and some of the model's variables; e.g., the U.S. interest rate is negatively correlated

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1/ This approach weights all regime changes equally, in essence assigning no more weight to a major devaluation than to a small devaluation or to an adjustment of the exchange rate regime towards a more flexible system.

2/ Logit and probit models are known to be sensitive to misspecifications (see Kennedy (1992), p. 236). In particular, estimates may be inconsistent (i.e., the parameter's estimate does not approach its true value as the sample size gets larger) if a relevant explanatory variable is excluded from the regression, or if the error term is heteroskedastic (i.e., the variance of the error term is not constant over time). Tests for the presence of possible misspecifications, such as heteroskedasticity and omitted variables, were examined and reported in Appendix II. In general, the qualitative results of this and the next section appear to be robust.

3/ The use of the logarithm of the U.S. price level, in place of inflation differentials, reduces somewhat the magnitude of the associated probabilities, but does not affect the qualitative results.

4/ The results do not change when the U.S. treasury bill rate or the U.S. dollar Libor rate are used.

Table 3. Mexico: Empirical Results 1/

	(1)	(2)	(3)	(4)
Constant	2.412	10.620	1.243	25.870
	(0.17)	(1.17)	(0.06)	(1.66)
$Log(D^b_{t-1})$	0.394**	0.821*	--	--
Central bank credit to banks	(1.88)	(2.06)	--	--
Def_{t-2}	--	--	$0.13e^{-3}$*	$0.21e^{-3}$
Deficit	--	--	(2.82)	(1.33)
u_{t-1}	1.806	--	9.375**	--
Competitiveness	(0.58)	--	(1.80)	--
CA_{t-2}	--	$0.60e^{-3}$	--	$-0.16e^{-2}$
Current account balance	--	(1.19)	--	(-1.08)
$(p-p^*)_{t-1}$	0.028*	0.017**	0.034*	0.038
Inflation differential	(2.42)	(1.87)	(2.04)	(1.33)
$Log(R_{t-1})$	-1.965*	-2.067*	-3.960*	-2.496**
Reserves	(-2.38)	(-2.28)	(-2.67)	(-1.74)
$\Delta Log\ (R_{t-1})$	-3.164	-4.489**	-2.245	-4.148
Reserves lagged	(-1.44)	(-1.79)	(-0.97)	(-1.60)
Δy_{t-1} 2/	0.243*	0.251*	0.336*	0.332*
Output growth	(2.80)	(2.77)	(2.46)	(2.58)
i^*_{t-1}	-0.128	-0.412	-1.750*	-1.112
U.S. money market rate	(-0.48)	(-1.01)	(-2.71)	(-1.56)
s_{t-1}	-0.220	-0.308	-0.352	-4.239
Upper bound on the exchange rate	(-0.42)	(-0.66)	(-0.57)	(-1.03)
Ln L	-17.25	-16.61	-13.19	-13.14
Log likelihood function				
Ln L_0 3/	-33.86	-33.86	-33.86	-33.86
LR Index 4/	0.49	0.51	0.61	0.61
R^2	0.44	0.40	0.51	0.51
Number of observations	147	147	147	147
(Number of devaluations)	(9)	(9)	(9)	(9)

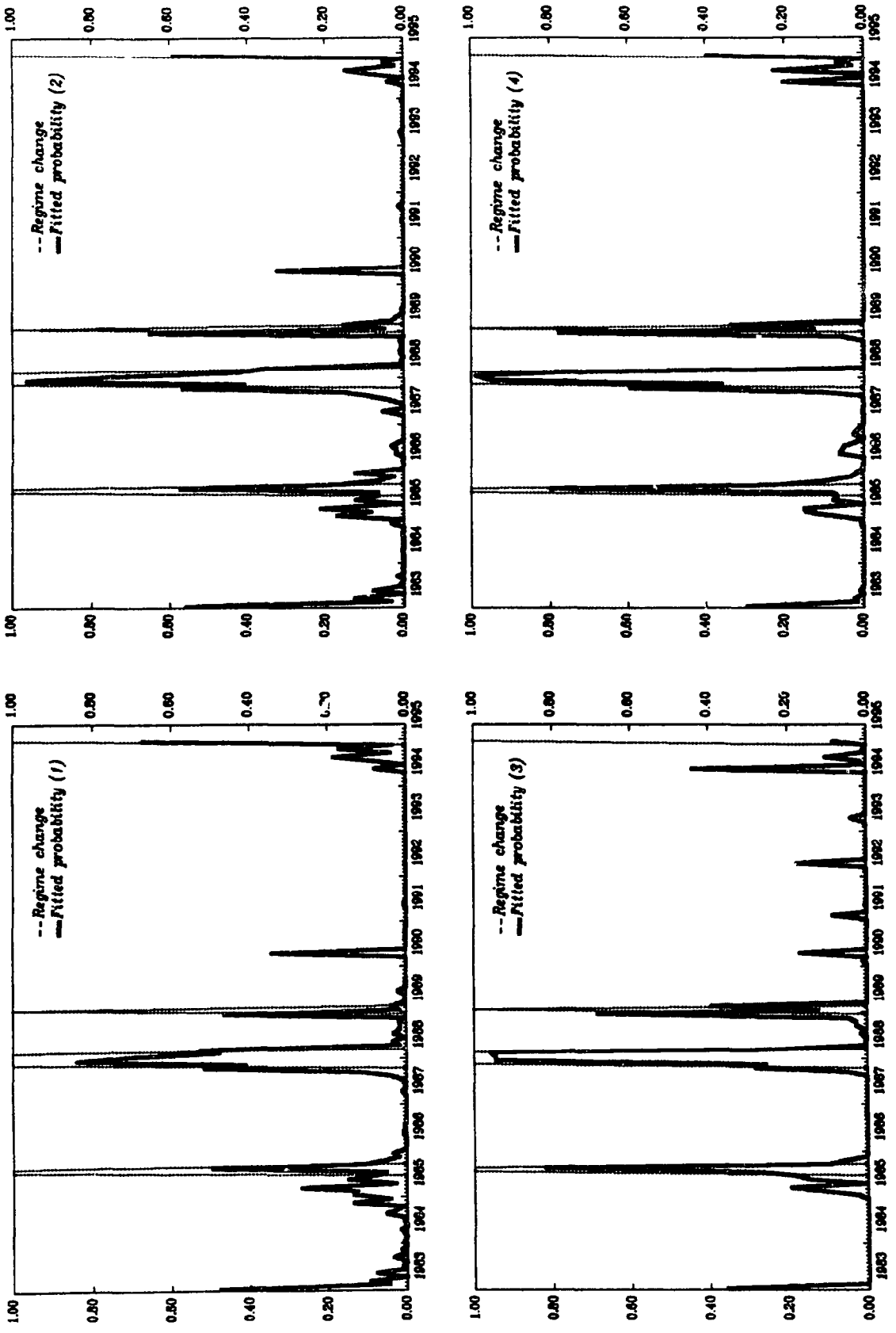
1/ T-ratios are given in parentheses. * and ** denote statistically significant statistics at the 5 percent and 10 percent levels, respectively.

2/ Seasonally adjusted.

3/ The Log likelihood function of a regression with only a constant term, i.e., with all slope coefficients assumed to be zero.

4/ The Likelihood Ratio Index (calculated as [1 - (Ln L)/(Ln L_0)]), analogous to the R^2 goodness of fit measure in conventional regression methods; a value close to zero indicates that explanatory variables have coefficients close to zero.

CHART 1
ONE-STEP AHEAD PROBABILITY OF A REGIME CHANGE 1/



1/ Fitted probabilities are computed by using the results of the estimation of the equations in Table 3.

with foreign exchange reserves (-0.77) and the credit-to-the-banking system variables (-0.68), and positively correlated with the deficit variable (0.58) and the current account variable (0.81). Nevertheless, the statistical insignificance of the sign of the U.S. interest rate suggests that investors assigned greater weight to other fundamentals than interest rate differentials when forming their decisions. 1/

Mexico undertook major domestic financial sector reforms and capital account liberalization in 1989. In order to assess the impact on the results of the structural changes since, a dummy variable, which takes the value one for the period after 1989, was included, allowing also for multiplicative interaction of this dummy variable with the explanatory variables. The coefficients of the slope dummies for the credit to the banking sector, the real exchange rate, and inflation differentials for the post-1989 period were significantly positive, implying that the effect of these variables became stronger after the introduction of financial sector reforms. For the post-1989 period, the coefficient of the U.S. interest rate becomes positive, but remains insignificant. For the rest of the variables, there was no significant evidence of a structural break.

As regards the predictive power of the model, fundamental variables generate quite high (mostly over 50 percent) one-step-ahead probabilities for the regime changes that took place in Mexico during the sample period (Chart 1). Furthermore, the use of fiscal deficit as an explanatory variable leads to far better predictions for the regime changes in the period before the abolition of the dual exchange rate system (before November 1991). 2/ When the central bank credit to the banking system is used instead in the estimation, the probability of the last devaluation increases significantly, to about 67 percent, compared with about 10 percent

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1/ When multicollinearity between any two explanatory variables is severe, a restricted model, from which the variable that is expected to cause the multicollinearity problem is excluded, may be preferable (Griffiths et al. (1987)). However, the omission of an explanatory variable to correct for one source of misspecification may result in another sort of misspecification, as the parameter estimates in a restricted model may become inconsistent with the exclusion of this variable. In order to see whether the omission of the U.S. interest rate from the model is warranted, some omitted variables tests were performed (see Appendix II). According to the test results, the exclusion of the U.S. interest rate may be warranted when the credit-to-the-banking system variable is used, as opposed to when the deficit variable is used.

2/ The inclusion of credit to development banks in the deficit figures does not change the results.

with the deficit variable. 1/ This finding is consistent with the observation (see e.g., Calvo (1995) and Sachs et al. (1995)) that it was mainly the rise in the indebtedness of the private sector rather than that of the public sector that contributed to the tensions in the foreign exchange markets in late 1994, and provides some empirical evidence contrary to the Lawson-Robichek argument; this argument claims that the government should not worry if the private sector runs current account deficits as long as there is no fiscal deficit. 2/ In that respect, the authorities' decision to extend domestic credit to the banking system to sterilize the reserve losses may in fact have contributed to the crisis. However, one also needs to take into consideration the potential negative impact, in the absence of sterilization, of higher interest rates on the financial situation of the Mexican banks, which were already experiencing difficulties in an environment with high real interest rates and with non-performing loans of about 8.5 percent of total loans in March 1994. 3/

As indicated in Chart 1, the model yields some positive probabilities of devaluations for the periods preceding the regime changes, which are indicative of tensions in the exchange markets. The model also gives a

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1/ Including both the deficit and the credit to the banking system variable yields much higher probabilities for those regime changes before 1994 compared with the use of the credit variable alone and approximately the same probabilities compared with the use of the deficit variable alone. The probability of the 1994 regime change, however, turns out to be in a range of 25-37 percent (a much lower probability than the 67 percent obtained with the credit variable alone), depending on whether the variables are used in combination with competitiveness or the current account deficit, respectively.

2/ Using a theoretical framework, Calvo (1995) demonstrates that a balance of payments crisis of the Krugman type will take place even though there is no fiscal deficit during the fixed rates period. In Mexico, indebtedness of the private sector, which financed the recent consumption boom might have fueled individuals' expectations that the exchange rate policy was unsustainable. Furthermore, Calvo (1995) argues that the consumption boom exaggerated the fiscal surplus in Mexico by boosting indirect tax revenues. A cyclically adjusted fiscal deficit would probably capture this effect, but is difficult to derive due to data availability.

3/ The Bank of Mexico argues, in its 1995 report, that in 1994 it implemented monetary policy measures in accordance with the general guidelines established by its Board of Governors. These guidelines include adjusting the daily supply of base money in order to satisfy its expected demand given market interest rates, provided that the inflation target will not be jeopardized. If, for some reason (including emergence of exchange rate pressures), compliance with the inflation target were in jeopardy, the Bank would continue to meet daily demand for base money, but at higher interest rates. As Sachs et al. (1995) also point out, interest rates went up in Mexico in light of the March 1994 shock, but perhaps not enough to prevent the outflow of capital or to reduce the large current account deficit.

significant positive probability for April 1990, reflecting the sharp decline (about $3.6 billion) in foreign exchange reserves in March 1990. Since no regime change actually occurred in these periods, the positive probabilities can be interpreted as indicating unsuccessful attacks. Furthermore, the relatively high probabilities ahead of the mid-1985 regime changes reflect the pressures that led the authorities to increase the rate of crawl (the periodic depreciation rate) of the exchange rate in December 1984 and March 1985. In addition, the estimated probabilities appear to indicate a build-up of pressures on the currency since mid-1994 (particularly when the central bank credit to the banking system is used), leading up to the "postponed" exchange rate adjustment of end-1994.

Finally, the computation of the out-of-sample predictions for 1994 using the central bank credit to the banking sector as a proxy for expansionary policies generates very high probabilities of a regime change for the second and third quarters of 1994. The out-of sample predictions, which were obtained by applying the estimation results over the 1982-93 period to the January-August 1994 period, indicate that the probability of devaluation jumped to about 49 percent in May from about zero percent in the previous month, and to 65 percent and 84 percent in July and August 1994, respectively (Chart 2). In contrast, using the fiscal deficit as a proxy for expansionary policies generated poor out-of-sample predictions.

VII. Further Empirical Considerations and Policy Implications

This section discusses the sensitivity of the empirical results to alternative assumptions regarding the impact on the exchange rate crises of the changes in the structure of Mexico's debt, and the timely availability of economic and financial data.

In addition to the emergence of internal and external macroeconomic imbalances and the problems in the banking sector, an important element of the 1994-95 Mexican financial crisis was the concentration of the government debt at the short end of the maturity spectrum, as well as the currency composition of the debt. 1/ As a result of the events in early 1994 and the associated financial pressures, the Mexican authorities shifted to shorter-term dollar-indexed debt (tesobonos) from peso-denominated debt (cetes) during 1994. Indeed, the share of tesobonos in total government debt increased from about 6 percent in February 1994 to 66 percent by end-November.

An increase in the share of foreign-indexed debt can in principle provide the central bank with borrowed reserves which could help sustain the fixed exchange rate system. However, as the share of this short-term debt becomes increasingly higher, rational investors expect that the government will not be able to honor its debt at maturity and will not be able to roll

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1/ See International Monetary Fund (1995a), pp. 53-64.

it over as investors would not want to hold any more debt. 1/ Following this argument, the share of short-term foreign-currency indexed government securities in total government securities is included as one of the explanatory variables in the regressions, in order to test the contribution of the shift in the structure of Mexico's short-term government debt to the tensions in the financial markets. 2/3/ The results of the regression analysis are presented in Table 4.

In general, the share turns out to have a positive, though statistically insignificant, coefficient. Despite its insignificance, however, the model's fit for the 1987 and 1994 regime changes improve substantially (Chart 3). Specifically, when the share is used together with the deficit and competitiveness variables, the probability of regime changes in December 1987-February 1988 increases from about an average of 95 percent to almost 100 percent, and the probability of the December 1994 devaluation increases by almost 50 basis points; the improvement is less pronounced, however, when the credit-to-the-banking system or current account variables are used. The latter might reflect the strong correlation between the share variable and the credit to the banking system (0.67) on the one hand, and the current account (-0.57) on the other. In any case, these results underscore the impact of the switch to short-term foreign-currency debt on the sentiment in foreign exchange markets, as market participants became increasingly concerned about the amount of tesobonos that would mature in the short run. 4/

1/ Calvo (1995) outlines a model in which the fiscal authority covers revenue shortfalls by floating increasing amounts of debt with short-term maturity. The main results of the analysis are that the timing of the speculative attack is a function of the amount of bonds that will be redeemed once the regime change takes place, and that the balance of payments crisis occurs earlier than without bonds.

2/ It should be noted that equation (3) of the theoretical model discussed in section IV assumes uncovered interest parity. To incorporate the analysis of the share of foreign-currency debt (FD), the model could be extended by including a risk premium in equation (3), which may be assumed to be a function of certain factors, including FD:

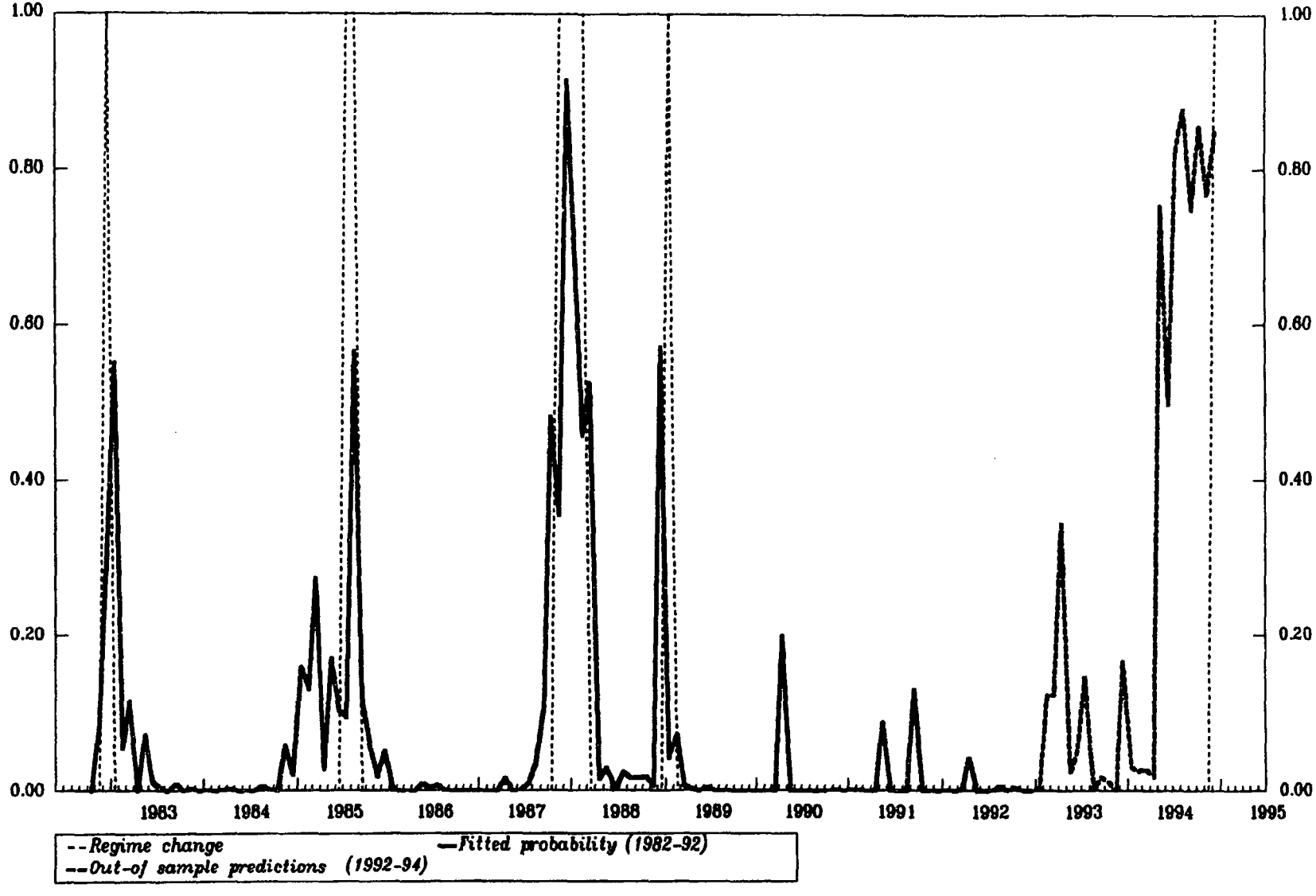
$$i_t = i_t^* + Ee_{t+1} - e_t + \rho_t \,, \quad \text{where } \rho_t = \rho(FD_t, \ldots) \qquad (3')$$

3/ Mexican government issued two types of foreign-currency indexed short-term government securities: pagafes and tesobonos. Pagafes were issued during 1986-1992, and tesobonos have been issued since July 1989. The share of short-term foreign currency debt included in the regressions is the total share of these two instruments in total short-term government securities.

4/ The omitted variables tests that are also conducted for this variable (see Appendix II) provide strong support for its inclusion in the regression equation with the deficit and competitiveness variables, while the support is weak when the credit and current account variables are used.

CHART 2

ONE-STEP AHEAD PROBABILITY OF A REGIME CHANGE: OUT-OF-SAMPLE PREDICTIONS FOR 1992-94 PERIOD 1/



Source: Fitted probablities and out-of-sample predictions are computed by using the results of the estimation of equation (1) in Table 3.

Table 4. Mexico: Empirical Results 1/

	(5)	(6)	(7)	(8)
Constant	1.657	12.388	-8.638	30.211
	(0.11)	(1.21)	(-0.27)	(1.52)
$Log(D^b_{t-1})$	0.491	0.807**	--	--
Central bank credit to banks	(1.54)	(1.89)	--	--
Def_{t-2}	--	--	$0.35e^{-3}$	$0.26e^{-3}$
Deficit	--	--	(1.57)	(1.25)
u_{t-1}	1.957	--	12.827	--
Competitiveness	(0.61)	--	(1.38)	--
CA_{t-2}	--	$0.28e^{-2}$	--	$0.19e^{-2}$
Current account balance	--	(1.40)	--	(0.56)
$(p-p^*)_{t-1}$	0.028*	$0.33e^{-3}$	0.074	0.022
Inflation differential	(2.39)	(0.02)	(1.55)	(0.57)
FD_{t-1}	$-0.02e^{-2}$	0.286	0.240	0.516
Share of foreign currency debt	(-0.42)	(1.16)	(1.14)	(1.08)
$Log(R_{t-1})$	-2.031*	-2.146*	-3.976**	-2.795
Reserves	(-2.37)	(-2.09)	(-1.75)	(-1.58)
$\Delta Log\ (R_{t-1})$	-3.387	-4.114	-3.937	-4.621
Reserves lagged	(-1.48)	(-1.49)	(-1.20)	(-1.44)
Δy_{t-1} 2/	0.252*	0.223*	0.373**	0.347*
Output growth	(2.76)	(2.17)	(1.78)	(2.12)
i^*_{t-1}	-0.156	-0.417	-2.668**	-1.236
U.S. money market rate	(-0.57)	(-0.88)	(-1.65)	(-1.45)
$\bar{e}_{t-1}$	-0.222	0.201	-4.742	-4.588
Upper bound on the exchange rate	(-0.41)	(0.33)	(-1.17)	(-0.89)
Ln L	-17.17	-15.27	-9.69	-11.22
Log likelihood function				
Ln L_0 3/	-33.86	-33.86	-33.86	-33.86
LR Index 4/	0.49	0.55	0.71	0.67
R^2	0.42	0.45	0.62	0.59
Number of observations	147	147	147	147
(Number of devaluations)	(9)	(9)	(9)	(9)

1/ T-ratios are given in parentheses. * and ** denote statistically significant t-statistics at the 5 percent and 10 percent levels, respectively.

2/ Seasonally adjusted.

3/ The Log likelihood function of a regression with only a constant term, i.e., with all slope coefficients assumed to be zero.

4/ The Likelihood Ratio Index (calculated as [1 - (Ln L)/(Ln L_0)]), analogous to the R^2 goodness of fit measure in conventional regression methods; a value close to zero indicates that explanatory variables have coefficients close to zero.

In estimating the one-step ahead probability of a regime change in period t, information available in the period t-1 had been used. In order to evaluate the usefulness of this paper's approach as an early warning device, it is possible to consider alternative specifications regarding availability of data. In particular, it has been indicated that the sharp decline in the Bank of Mexico's reserves in November was not publicly announced until after the peso was devalued in December. 1/ In that case, using November reserves in estimating the regime change in December might predict the December devaluation only from the perspective of the authorities, to whom it might have become apparent that the prevailing peg could not be maintained at the existing parities and prevailing level of reserves. On the other hand, speculators might not have been able to predict that devaluation, as they were not endowed with the most recent information on foreign exchange reserves in November. Accordingly, the model was estimated again, but this time by using two-period lagged reserves variable, as opposed to one-period lagged one. The results did not change qualitatively, and the predicted probabilities of the previous regime changes remained more or less unchanged, although the probability of devaluation in December was reduced. However, the model still predicted the existence of speculative pressures during several months ahead of December. This finding implies that even without full information about the decline in reserves, speculative pressures were evident, given the deterioration in some of the economic fundamentals.

Finally, in order to address other potential information problems and to test the predictive capacity of the model sufficiently ahead of time, the model was estimated by using different lag structures for all the model's explanatory variables. Using up to five-period lags, the significance level of the coefficients declined and the associated probabilities were reduced for most of the regime changes. Nevertheless, the model still predicted the existence of turbulence before the regime changes (Charts 4 and 5). In particular, when the share of foreign-currency-indexed debt was used as one of the explanatory variables, the model's fit for the 1994 crisis improved. Given the lead time of three to five months implied by the results, the model could possibly be of some limited use as an early warning device, or sign of impending trouble. The reduction in the predictive power, on the other hand, also underscores the importance of access to timely economic and financial data for enhanced surveillance in the future. 2/

VIII. Concluding Remarks

Following periods of turbulence caused by political and economic uncertainties, the Mexican new peso came under speculative pressure at the

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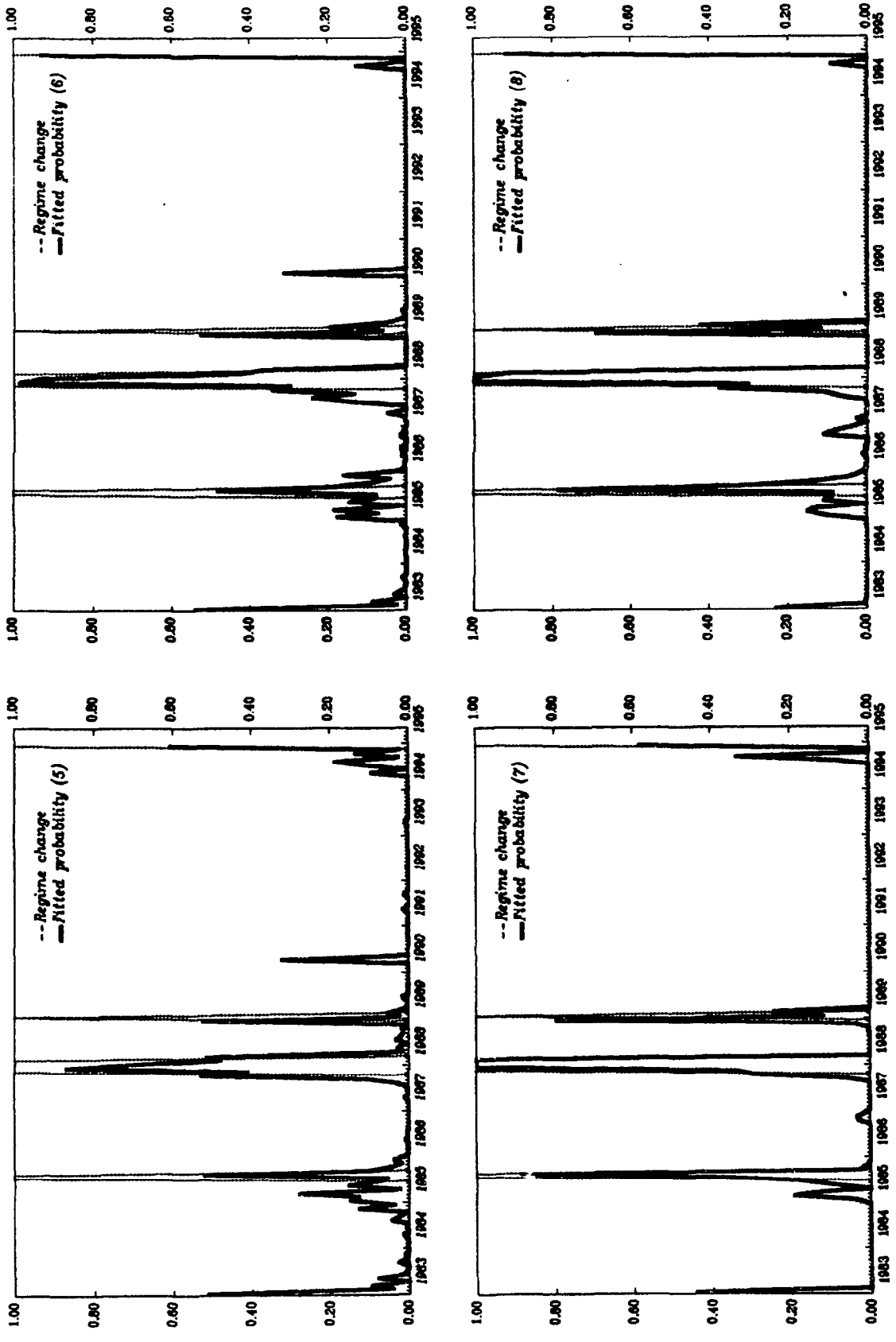
1/ See International Monetary Fund (1995a), pp. 53-64.

2/ It should be noted that the scope and quality of economic and financial data being made available by the Bank of Mexico to the IMF, as well as for publication, have improved substantially since the outbreak of the financial crisis at the end of 1994.

CHART 3

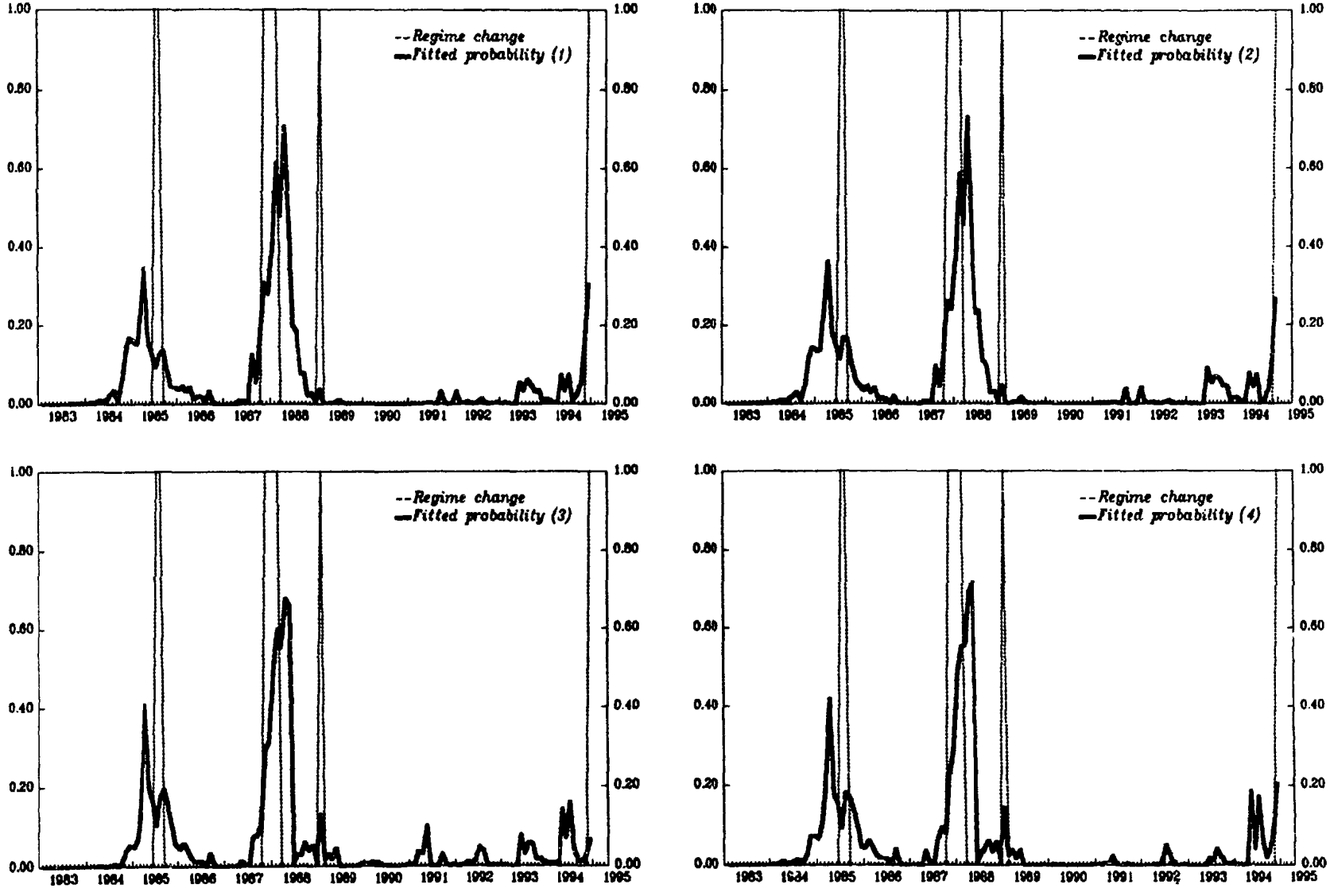
ONE-STEP AHEAD PROBABILITY OF A REGIME CHANGE 1/



1/ Fitted probabilities are computed by using the results of the estimation of the equations in Table 4.

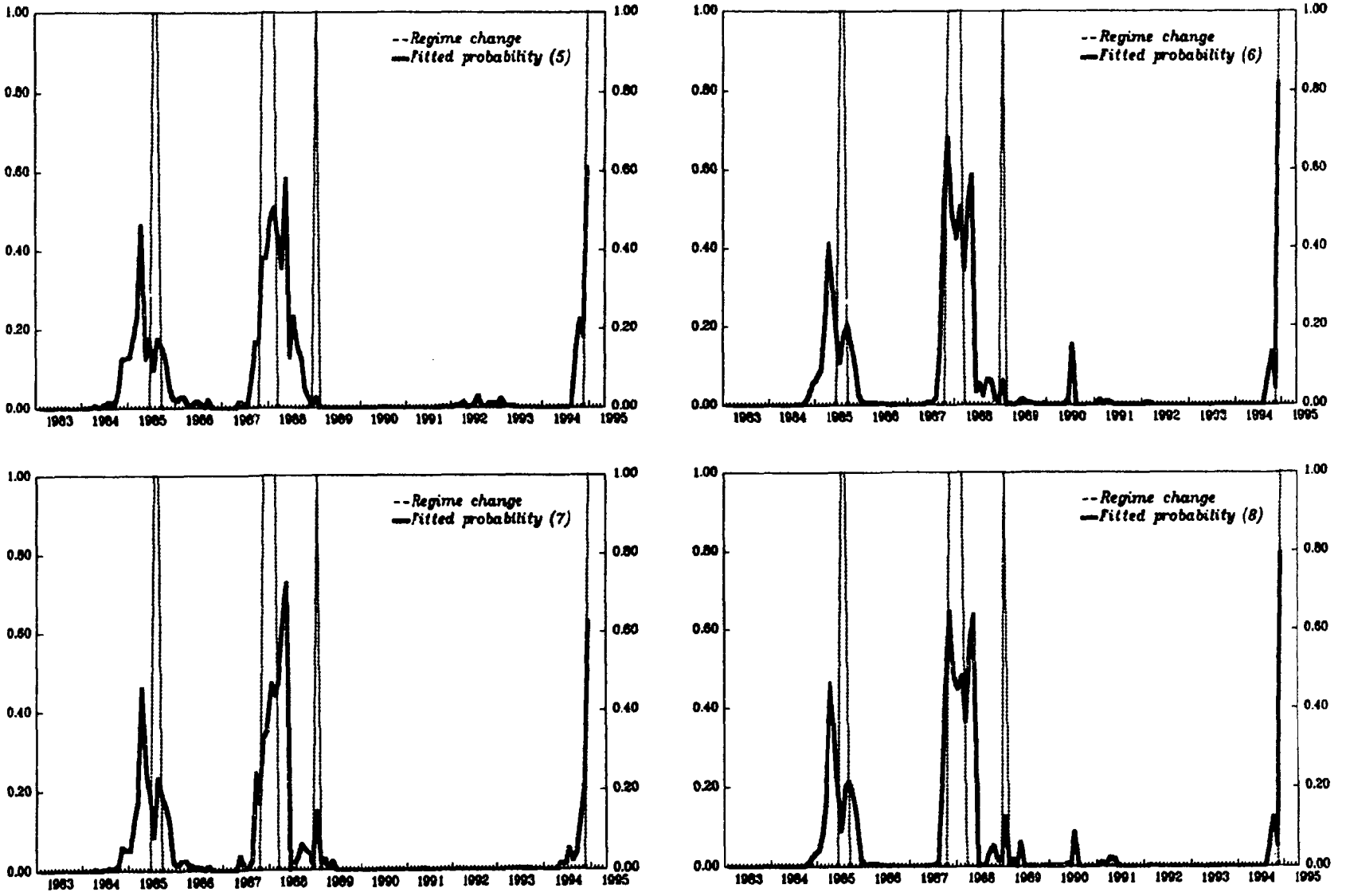
CHART 4

PROBABILITY OF A REGIME CHANGE: WITH FIVE-MONTH LAGGED INFORMATION 1/



1/ Fitted probabilities are computed by using the results of the estimation of the five-month lagged specification of the equations in Table 3.

CHART 5
PROBABILITY OF A REGIME CHANGE:
WITH FIVE-MONTH LAGGED INFORMATION 1/



1/ Fitted probabilities are computed by using the results of the estimation of the five-month lagged specification of the equations in the Table 4.

end of 1994. The Mexican authorities devalued the currency on December 20, 1994, and subsequently abandoned the crawling band exchange rate mechanism that had been in effect since November 1991, as continued selling pressures on the currency reduced the foreign reserves of the Bank of Mexico. While the Mexican crisis in end-1994 and the subsequent turbulence in the foreign exchange markets were unprecedented, Mexico's history on exchange rates indicates that Mexico has often experienced setbacks in its efforts to permanently stabilize its economy using a pegged exchange rate regime.

In this paper, we examined the changes in Mexico's exchange rate regime in the period 1982-94 in an attempt to identify the role of Mexico's macroeconomic fundamentals in exerting pressure on the peso, and to evaluate whether the associated regime changes could be explained by a deterioration in these fundamentals. In order to identify their contribution, we computed the probability of a regime change as a function of economic fundamentals by using a model based on the speculative attack literature. The empirical findings indicate that, in general, the deterioration in economic fundamentals generate high one-step-ahead probabilities for the regime changes that took place in Mexico during the sample period. In particular, the sharp increase in inflation differentials vis-à-vis the United States in 1987-88, the appreciation of the real exchange rate since 1987, the periodic sharp losses of foreign reserves, and/or expansionary monetary and fiscal policies appear to have contributed to the pressures that resulted in the regime changes during the estimation period.

Furthermore, our empirical results suggest that the rise in the private sector indebtedness, instead of public sector imbalances, was in part responsible for the foreign exchange crisis in late 1994. The significant build-up of pressures on the currency since mid-1994 was evident in the estimated probabilities, particularly when the central bank credit to the banking system was used as an explanatory variable; indeed, the probability of a regime change surged to about 70 percent in December 1994 from about one percent in June. 1/ In addition, the sharp losses of foreign reserves appear to have been crucial (as outlined in the speculative attack literature) in shaping the authorities' decision to abandon the crawling band regime in 1994. Furthermore, the improvement in the model's fit obtained by the inclusion of the share of shorter-term foreign-currency-indexed debt underscores the importance of the switch to tesobonos in creating further pressures on the currency.

Finally, the recent experience of Mexico also illustrates that the sustainability of exchange rate policy depends crucially on adequate policy

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1/ If the central bank credit to the banking system is used in combination with the fiscal deficit, the probability of the December devaluation declines to about 30 percent, implying the offsetting impact of the improvement in the fiscal position; although this is relatively a small number, the jump in the probability from about zero percent to 30 percent suggests the presence of significant pressures in the market.

responses to shocks to the economy and on the extent of fragility of the economic and financial system. While the unfolding of events leading to the recent crisis in Mexico followed a course different from that suggested in the speculative attack literature, i.e., that reserve losses initially occurred due to domestic political tensions, rather than to monetary and fiscal imbalances, our results suggest that the subsequent efforts of the authorities to sterilize these reserve losses by extending credit to the banking system (given the poor quality of bank portfolios and already high real interest rates) and increasing switch to tesobonos may have contributed to further losses of reserves. 1/2/

1/ Sachs et al. (1995) (pp. 7-10) develop a similar argument, and demonstrate the link between reserve losses and sterilization policy under the policy of restraining interest rate rises.

2/ A tightening of credit supported by a more restrictive fiscal stance might have been needed to stave off the pressures on the exchange rate regime. "However, the effects of the credit tightening on output and the solvency of the banking system may not have been qualitatively different from those that seem to have arisen in the aftermath of the December crisis." (See International Monetary Fund (1995b)).

Description of Data

This appendix provides the description of the monthly data used in the empirical analyses.

E: The level of the end-of-period spot exchange rate, i.e., the price of the U.S. dollar in terms of the Mexican peso. Sources: IFS (line we, International Monetary Fund, Central Bank of Mexico).

e: The log of the end-of-period spot exchange rate, E.

$\bar{e}$ The upper bound on the exchange rate. Source: staff calculations and Table 1.

i^*: Short-term money market rate for United States. Source: IFS, International Monetary Fund.

R: The central bank total reserves minus gold. Source: IFS (line 11.d), International Monetary Fund.

D: Total domestic credit (in domestic currency). Source: IFS (line 32), International Monetary Fund.

D^b: Net domestic credit extended by the central bank to the banking system. Source: IFS, International Monetary Fund.

Def: Central budget deficit. Source: Mexican Authorities.

FD: The share of foreign-currency indexed debt in total short-term government securities. Source: IBAMEX Database, Bank of Mexico.

y: The log of industrial production index. Source: IFS (line 66.c), International Monetary Fund.

u: The log of the real effective exchange rate index based on relative consumer prices. Source: IFS, International Monetary Fund.

CA: Current account balance, extrapolation of quarterly current account data by using monthly trade balance. Source: IFS (lines 70, 71, 77a.d, 77acd), International Monetary Fund.

p: The log of the Mexican consumer price index. Source: IFS (line 64), International Monetary Fund.

p^*: The log of the U.S. consumer price index. Source: IFS (line 64), International Monetary Fund.

Tests for Misspecification

1. Test for heteroskedasticity

It is often acknowledged that it is important to test for heteroskedasticity of disturbance terms in qualitative dependent variable models, because this specification leads to inconsistent parameter estimates. Residuals are heteroskedastic when their variances are not constant over time, i.e.,

$$Var(u_i) = \sigma_i^2 = \sigma^2 r_i^2, \text{ where } r_i = h(z_i'\alpha), \ i=1,2,\ldots,n,$$

σ^2 is some positive constant, z_i represent a subset of exogenous variables of the model, and $h(.)$ is a twice differentiable function. Testing for heteroskedasticity involves testing the null hypothesis H_0: $\alpha = 0$.

Godfrey (1988) 1/ provides a Lagrange multiplier (LM) test to check for heteroskedasticity of the above form. The test involves calculating a test statistic which is the explained sum of squares for the OLS regression of the variable:

$$[y_i-(1-F(x_i'\beta^*))]/[F(x_i'\beta^*)(1-F(x_i'\beta^*)]^{1/2}$$

on the variables

$$[-(x_i'\beta^*)z_i', x_i'] f_i(x_i'\beta^*) / [F_i(x_i'\beta^*)(1-F_i(x_i'\beta^*)]^{1/2}$$

where, functions F_i and f_i are evaluated at the maximum likelihood estimators, β^*, that are obtained under the assumption of homoskedasticity. In probit models,

$$F_i(x_i'\beta^*) = 1-\Phi(x_i'\beta^*), \ f_i(x_i'\beta^*) = \phi(x_i'\beta^*),$$

where $\Phi(.)$ and $\phi(.)$ are the cumulative distribution function and the probability density function of the disturbance term, respectively. This LM test statistic has a Chi-square ($\chi 2$) distribution with degrees of freedom given by the number of non-constant regressors in the regression. The null hypothesis of no heteroskedasticity is rejected when the computed test statistic exceeds the critical $\chi 2$ value for the same degrees of freedom (or

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1/ See pages 214-217.

alternatively, when the p-value from the regression is less than 0.01). The results of this test, provided in Table 5 below, suggest that the results are robust to heteroskedasticity.

Table 5. Test for Heteroskedasticity

Variables included in the probit estimation	LM Test statistic (χ^2 (p)) 1/ 2/	Critical χ^2 value for p=19 and 95 percent
$Log(D^b_{t-1})$, u_{t-1}, $(p-p^*)_{t-1}$, FD_{t-1}, $\bar{e}_{t-1}$ $Log(R_{t-1})$, $\Delta Log(R_{t-1})$, Δy_{t-1}, i^*_{t-1}	$\chi^2(19)$= 5.125 (0.999)	30.14
(Def_{t-2}), u_{t-1}, $(p-p^*)_{t-1}$, FD_{t-1}, $\bar{e}_{t-1}$ $Log(R_{t-1})$, $\Delta Log(R_{t-1})$, Δy_{t-1}, i^*_{t-1}	$\chi^2(19)$=11.422 (0.909)	30.14
(Def_{t-2}), CA_{t-2}, $(p-p^*)_{t-1}$, FD_{t-1}, $\bar{e}_{t-1}$ $Log(R_{t-1})$, $\Delta Log(R_{t-1})$, Δy_{t-1}, i^*_{t-1}	$\chi^2(19)$=12.067 (0.883)	30.14

1/ p is the number of nonconstant explanatory variables in the regression.
2/ The numbers in parentheses indicate p-values from the OLS regression.

2. Tests for omitted variables

If there is a high degree of multicollinearity between a model's variables, a restricted model might be preferable in which the variable which is most likely to cause the multicollinearity problem is excluded from the model. On the other hand, if a relevant variable is omitted from the model, the coefficient of the included variable will be inconsistent (i.e., the value of the parameter estimate does not approach the true value of the parameter in the limit). In that case the exclusion of the variable might not be warranted. The Likelihood Ratio *(LR)* statistic can be used to test for omitted variables, which involves testing whether $b_2 = 0$ in:

$$H_0: y = b_1X_1 + e,$$
$$H_1: y = b_1X_1 + b_2X_2 + e.$$

If L_1 is the maximum value of the likelihood function of the unconstrained model in H_1, and L_0 is the value when the constraint is imposed, then the LR test is computed as:

$$LR = 2\ (L_1-L_0).$$

LR statistic has an asymptotic Chi-square (χ^2) distribution with degrees of freedom equal to the number of constraints. If the calculated χ^2 statistic *(LR)* exceeds the critical χ^2 value, then H_0 can be rejected; this means that the omission of X_2 is not warranted.

Table 6 below provides the results for all specifications used in the paper to test whether (i) U.S. interest rates and (ii) the share of short-term foreign currency debt can be omitted from the model. According to the test results, the exclusion of the U.S. interest rate may be warranted when the credit-to-the-banking system variable is used, as opposed to when the deficit variable is used. Similarly, the tests provide strong support for the inclusion of the share of foreign currency denominated debt in the regression equation with the deficit and competitiveness variables, while the support is weak when the credit and current account variables are used.

Table 6. LR Tests for Omitted Variables

Variable omitted	Calculated test statistic (LR)	Critical χ^2 value at p-1, 95 percent
i^*_{t-1}:		
in Specification (1)	0.24	3.84
(2)	1.30	3.84
(3)	13.13	3.84
(4)	4.30	3.84
(5)	0.34	3.84
(6)	1.11	3.84
(7)	7.38	3.84
(8)	3.92	3.84
FD_{t-1}:		
in Specification (1)	0.16	3.84
(2)	2.67	3.84
(3)	7.00	3.84
(4)	3.84	3.84

Source: Tables 3 and 4.

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