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**COLLAPSING CONTROLLED EXCHANGE RATES:**
How well can we predict and explain them?

**Valentijn van Nieuwenhuijzen**

CPB Netherlands Bureau for Economic Policy Analysis, The Hague, January 1999

CPB Netherlands Bureau for Economic Policy Analysis
Van Stolkweg 14
P.O. Box 80510
2508 GM  The Hague, The Netherlands

Telephone  +31 70 33 83 380
Telefax  +31 70 33 83 350

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## 1. Introduction

That collapsing exchange rates can pose a threat to economic and social stability in a country is something you hardly have to explain these days. Recent financial crises in South-East Asia and before that in Latin America and Europe, have made it very clear that the crash of a fixed exchange rate regime can have significant, negative effects on the real economy. Therefore, the importance of determining what causes the collapse of fixed or otherwise controlled exchange rates is obvious. To achieve the latter, however, it is of primary importance to know why controlled exchange rates are introduced in the first place and how they are maintained.

It is often argued that controlled exchange rates are a good thing to control inflation rates, stabilize economic growth and to stimulate international trade by decreasing exchange rate risks for traders partners. A lot of countries all over the world are attracted to these potential benefits and fix or peg their currency against one of the world's major currencies or a basket of several currencies. To make such a regime sustainable, however, serious fiscal and monetary policy support is needed. Since most currencies are traded world wide on international capital markets, credibility and quality of the economic policies of a country are of crucial importance for the survival of an exchange rate system.

Good economic conditions and faith in solid economic policy in the future are important factors for an investor to determine how reliable it is to invest in a certain currency. Investors that do no longer have confidence in the economic perspectives of a country, will fear a future drop in the value of that country's currency and will move their capital to other assets (often other currencies) with less expected risk of losing value in the future. This leads to a large increase in the supply of a currency and a drop in demand for that currency and, as a results of that, a decrease in the price of that specific currency. Since such a devaluation of a currency can have seriously destabilizing effects on a country's economy the government of that country will try to develop credible policies that give investors confidence about the future economic performance of the country and the government's commitment to stabilizing the exchange rate.

To fix an exchange rate or to control the rate of domestic currency depreciation the monetary authority of a country has to pursue a specific exchange rate policy. This is mainly done by controlling the domestic money market conditions. Through the money market a government or central bank has several ways to fix or peg the exchange value of its currency. If the financial markets in a country are properly functioning it is possible to use open-market operations, intervention in the forward exchange market, direct operations in foreign assets and changes in the commercial bank reserve requirements to defend the exchange parity.

When a country has a fixed exchange rate regime or a regime of currency that depreciates at a predetermined rate, a crawling peg, then foreign exchange market participants will take that into consideration when forming their future expectations. They will understand that the exchange rate regime will be maintained as long as it does not conflict with other, more important, economic policies or political constrains. If investors believe that the exchange rate regime will be altered eventually, they can precipitate several events that test the credibility of the commitment and the ability of the monetary authority to defend the exchange rate regime. This is done because all of the policy instruments available to the monetary authority have only limited power. A country with an overvalued real exchange rate and excess domestic credit creation can only achieve money market equilibrium through offsetting reductions in the central bank foreign reserves or by adjusting the exchange rate. If a country tries to prevent its currency from depreciating it might find itself running out of foreign reserves and reaching it's borrowing limits. However, as long as foreign exchange reserves remain in positive supply, monetary authorities can succeed in sustaining a fixed exchange rate regime through the purchase of domestic currency and sale of foreign exchange reserves.

But if speculators perceive that an attack on the foreign reserves of the central bank can force the exchange rate regime to be abandoned, they will attack the domestic currency. By deleting the foreign reserves of the central bank the speculative attack will eliminate the central bank's ability to defend it's overvalued currency and force a realignment of the exchange rate. This realignment can take the form of either a discrete devaluation of a controlled exchange rate or a switch to a floating exchange rate regime.

So, if international investors are assumed rational and efficient, one would expect that the collapse of controlled exchange rate regimes can be explained on bases of the economic conditions in a country. Fundamental economic values, like domestic credit, the trade balance, international reserves and relative prices, should determine the sustainability of a fixed exchange rate regime. In the end, large international investors will or will not terminate the life of such a regime with a swift speculative attack, but in each case it would show to be a rational response to the fundamental economic conditions.

The economic theory on this subject has been worked out pretty well, but empirical testing of the developed theories and models has been very limited. Some models of collapsing exchange rates have been empirically tested and produced theory confirming results. In spite of that, a lot of doubt has risen about the general explanatory power of these collapse models. It is often argued, that irrational behavior or self-fulfilling panics among international investors are important driving forces of exchange rates. Therefore, models that try to describe collapsing exchange rate regimes, should take this into account. The standard collapse models don't do that and make very simplifying assumption about expectations formation of investors and factors that influence these

expectations. The lack of testable models which try to incorporate these more '*psychological*' determinants of exchange rates is largely caused by the fact that there are hardly reliable data available on market expectations and the problems with heterogeneity of expectations between different investors.

Although the latter is an area of research of great interest and importance, this paper focuses mainly on the standard and testable collapse models, sometimes called first-generation models. The theoretical critique against first-generation models makes it interesting to empirically test the general explanatory power of such models. For the first time a standard collapse model is not only tested for one currency over a longer period of time, with several periods of speculative pressure, but also for several different currencies in the same time-span. A standard collapse model is applied to the Mexican controlled exchange rate in the 1990's and to several European currencies that participated in the European Exchange Rate Mechanism (ERM) in the '*crisis*' year of 1992. This allows one to determine how good the model works, under what conditions it works best and whether these kinds of models can be useful even if they do not always work well.

Since Mexico is a country with a long history of exchange rate crises and because the last peso-crisis from 1994 had such a large impact domestically as well as internationally some extra attention is given to the Mexican experience with collapsing exchange rate regimes. The latter is done in chapter four of the paper. The rest of the paper is organized as follows. Chapter two gives an overview of the theoretical and empirical work that has been done so far on speculative attacks and collapsing exchange rates. In the third chapter the model used for the empirical research is presented. Description of the empirical research and the model outcomes are given in chapter five, while a small summary and the concluding remarks are given in the final chapter.

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# 2. Theory of exchange rate crises

## 2.1 Stabilization programs and exchange rate policy

The recent financial crisis has brought the discussion about the merits of controlled nominal exchange rates as anti-inflationary devices to the core of the policy debate. The supporters of fixed exchange rates argue that such a regime provides an effective device for guiding a disinflation program. Furthermore, they argue that in the long-run a controlled exchange rate system tends to impose fiscal and monetary discipline.

Much of the enthusiasm for fixed exchange rates is rooted in the credibility and time consistency it provides to government policy. Without the existence of a controlled exchange rate regime, governments will be tempted to 'surprise' the private sector through unexpected devaluations. This temptation can be caused by labor market rigidities that prevent the economy from reaching full employment. These 'surprise' devaluations will move the government closer to their employment and growth objectives, but will also introduce an inflationary bias into the economy. However, eventually the public will become aware of this incentive faced by the authorities and will start anticipating the devaluations and, thereby, make them ineffective. The direct and undesirable consequence of the strategic interaction that will emerge between the government and the private sector is that the economy will reach a higher level of inflation.

The credibility problem for the government that arises in this situation can be solved by introducing a controlled exchange rate system. It has been argued that the adoption of a fixed exchange rate will constrain the ability of governments to surprise the private sector through unexpected devaluations. According to this view, under a fixed exchange rate regime promises of fiscal discipline will become credible and private sector actions will not show successive rounds of inflationary actions. Furthermore, since the exchange rate is a highly visible variable, the government can effectively signal its commitment to a stabilization program. In that regard it has a clear advantage over alternative anchors, such as the money stock or domestic credit.

Finally, the exchange rate anchor will, in the presence of consistent fiscal and monetary policies, place a ceiling on tradable goods inflation and will tend to reduce inflationary expectations and inflationary inertia. The speed at which inertia are actually reduced is important, because a very slow decline will generate a process of real exchange rate overvaluation and deterioration of international competitiveness that could end up placing the whole stabilization program in jeopardy. The possible emergence of an overvalued real exchange rate is, actually, one of the most important drawbacks of an exchange rate anchor program. Therefore, credibility of the policy and

a low degree of backward looking indexation are crucial conditions for a controlled exchange rate regime to survive.

The implication of all this is that authorities that are considering the implementation of a fixed exchange rate should be willing and able to also implement policies that assure that the fixed parity can be maintained. The fiscal situation has to be under control and changes in international reserves should not be sterilized by the central bank. A decline in reserves should produce a contraction in the money supply and, other things equal, should increase the interest rate. Maintaining this type of policy is not easy politically, since non-sterilized declines in reserves are translated into high real interest rates, reduced economic activity and high unemployment. Therefore, the credibility of such a system depends on the extent that the authorities are willing to play by the rules of the fixed exchange rate game.

## 2.2 Standard or 'first generation' models of exchange rate crises

The first generation of modeling of speculative attacks on unsustainable government price fixing policy was done by Salant and Henderson (1978). They developed the main ideas for the standard models in an application to a government policy to fix the price of gold. This model was later adapted by Krugman (1979) and Flood and Garber (1984a) for use in the foreign exchange market, specifically to model collapsing fixed exchange rate regimes. In this context the policy to be attacked is the fixed price of a foreign currency or the announced fixed exchange rate. In Krugman's model the financing of government budget deficits by issuing domestic credit lies at the root of an exchange rate crisis. An attack will occur as a country adopts high-priority expansionary policies inconsistent with long-term maintenance of the fixed exchange rate. When a country fully monetizes its budget deficit, the international reserves are slowly depleted and finally lost completely as result of a discrete speculative attack.

In such an attack scenario base money and its components, international reserves plus domestic credit, play dominant roles. Because perfect capital mobility, perfect foresight and a constant demand for real money balances are assumed in the standard collapse models, full monetization of government deficits results in a rise of net domestic credit that produces an excess supply of money that cannot be absorbed by inflation because of the fixed or pegged exchange rate. The latter means that domestic credit expansions result in an exactly equal decrease of reserves. Therefore, a fixed exchange rate regime will lead to perfect sterilization of reserve losses. Thus, money financing of the fiscal deficit is an inconsistent policy with a fixed exchange rate, because the international reserves will eventually be exhausted and the fixed exchange rate has to be abandoned. The standard model assumes that after the exchange rate collapse, the high-priority

policies of the country are unaltered and the exchange rate regime is switched to a sustainable alternative.

This kind of exchange rate crises can be even better understood by evaluating the incentives for international investors. With a government that pegs the relative rate of return on domestic- and foreign assets, investors wish to hold domestic and foreign assets in fixed proportions. The rebalancing of their portfolios, needed as result of growing domestic credit, is done by exchanging some of the additional domestic assets for foreign exchange reserves of the central bank. However, investors keep their portfolio proportions constant and exchange only a portion of the incremental supply of domestic assets. Therefore, the (shadow) exchange rate that would prevail if the fixed exchange rate policy is abandoned gradually depreciates over time. When the latter equals the current exchange rate, investors attack the fixed or pegged exchange rate, because otherwise arbitrage profits would be made available and market inefficiency implied.

In such a situation, with a currently pegged exchange rate that has to be abandoned eventually as result of a steadily growing domestic credit stock, an exchange rate crisis is inevitable. The profit maximizing behavior of investors dictates that a strong speculative attack on the central bank's international reserves will occur at some point on the economy's path. This is an entirely rational market response to persistently conflicting internal and external macroeconomic targets.

It is important to note that in standard collapse models the foreseen speculative attacks are consistent with a private equilibrium. With perfect foresight the exchange rate cannot jump at the time of the attack, because otherwise agents could reap unbounded arbitrage profits. The prediction of the standard models is that the attack takes place at precisely the time the exchange rate does not need to jump. This is when the change in the money supply as result of the attack is exactly balanced by the change in money demand due to the interest rate effect of the policy change to a sustainable regime.

Crucial to the above logic is the assumption that the monetary authority does not sterilize the reserve loss at the time of the attack. Prior to the attack, the sum of domestic credit and reserves (base money) is constant with reserve losses sterilized exactly by increases in domestic credit. At the time of the attack, however, base money falls by the size of the reserve loss at the attack.

Flood and Garber (1984a) introduce uncertainty about the rate of domestic credit growth into the standard model. In their discrete-time model, unanticipated increases in domestic credit can cause the shadow exchange rate to exceed the fixed rate temporarily. As domestic credit grows, however, an attack becomes increasingly likely and the differential between domestic and foreign interest rates is widened. The larger the variance of the process governing the domestic credit creation, the greater the

probability of a regime shift and, therefore, the greater the probability of a speculative attack. The main points from the continuous time models are reproduced by the stochastic version of the standard model.

The empirical implications of these kind of models are that one should observe periods of expansionary fiscal and monetary policies prior to exchange rate crises. The standard models predict that speculative attacks on fixed exchange rates should be preceded by growing budget deficits and accelerating rates of monetarization or comparatively fast money growth. Further, one should expect real exchange rates to become overvalued and trade deficits to increase. Finally, declining stocks of foreign reserves, rising domestic interest rates, and weakening of forward exchange rates should be observed.

## 2.3 Second generation 'collapse' models with self-fulfilling speculative attacks

In the models described above, exchange rate collapses occur in a setting where the eventual abandonment of the fixed exchange rate regime is inevitable. So, a speculative attack only occurs as an entirely rational market response to persistently conflicting internal and external macroeconomic targets. It is often argued, however, that exchange rate crises could be caused by a contagious and collective panic in international capital markets, which is not based on certain developments of fundamental economic values. In those situations speculative attacks appear to be self-fulfilling, since they occur, for example, with a level of reserves which seems sufficient to handle the balance-of-payments deficit.

In the standard first generation models described above, a lower bound on reserves together with a steadily growing domestic credit stock makes a collapse of a fixed exchange rate regime inevitable. However, if domestic credit does not grow steadily or does not grow at all, then an exchange rate collapse becomes a probability-zero event in those models. The latter is caused by the assumption that no abrupt policy change will take place as result of a crisis. So, the domestic credit growth process does not change after a speculative attack. The central bank simply withdraws from the foreign exchange market when its reserves are exhausted and the exchange rate is allowed to float. However, as Obstfeld (1986) pointed out, when the assumption on policy changes is dropped, the situation changes and attacks become possible, even if the exchange rate would have been viable forever in the standard models.

A crisis induced policy change can, if anticipated, lead to indeterminacy of equilibrium and creates the possibility of a self-fulfilling speculative attack on exchange rates. If the central bank will switch to a more inflationary policy of more domestic credit growth after a fixed exchange rate collapse, then the exchange rate will make a

discrete jump and speculators could reap a capital gain. If the public expects the latter to occur a self-fulfilling speculative run can take place, because the authorities validate any run *ex post* by shifting to an inflationary policy. If and only if attacked, the authorities switch to a more accommodating policy consistent with a lower value of the exchange rate. Therefore, multiple equilibria exist because of the contingent nature of the authorities policy rule. In this context there are infinitely many self-fulfilling alternative equilibria. Each equilibrium corresponds to a different set of believes of the public about the probability of an attack.

In second generation models there is no reason to expect adverse trends in monetary and fiscal policies, foreign reserves or the trade balance prior to a speculative attack. In the period leading up to the exchange rate collapse no signs of trouble, such as expansionary fiscal policies, rapid money and credit growth, increasingly overvalued real exchange rates, and depletion of reserves, have to be visible. The shift of monetary and fiscal policies in a more expansionary direction should be observed after the rational self-fulfilling attack, according to the predictions of second generation collapse models. The stability of the fixed exchange rate regime is determined by the anticipated response to speculative pressure of the authorities.

## 2.4 Empirical testing of the collapse models

### 2.4.1 Estimation of standard collapse models

In the literature a lot of theoretical work is done on exchange rate crises and the predictability of speculative attacks. However, the collapse models that predict the timing and the probability of such attacks have not undergone much empirical testing. The latter seems strange, since the potential usefulness of this line of research has been shown by some authors. The first to do so were Blanco and Garber (1986), who applied Mexican data in a linear discrete time version of the standard collapse model to predict the timing and magnitude of devaluations caused by collapsing fixed exchange rate regimes. The results of their empirical work are encouraging. For the Mexican experience between 1973 and 1982 the collapse model predicted, both in and out of sample, high devaluation probabilities prior to actual devaluations. Also, the estimated expected exchange rate**,** if a devaluation would take place, is close to the actually realized values of the exchange rates in most periods.

Cumby and van Wijnbergen (1989) use a similar collapse model to make one-period-ahead estimates of the collapse probability of the Argentine crawling-peg regime between December 1978 and February 1981. They also estimated high collapse probabilities before the actual collapse occurred. Their main conclusion is that a specific exchange rate regime can only survive if the domestic credit policy is consistent with

the exchange rate policy of a country. If the latter is not the case credibility of the preannounced exchange rate regime is undermined and the exchange rate is forced to float in the end.

An other application of the standard model, with less restrictive assumptions, was done by Goldberg (1994). In the Goldberg (1994) model strict assumptions of purchasing power parity and the unresponsiveness of real money balances demand to currency substitution motives are no longer valid. This results in collapse probabilities that are still mainly driven by domestic credit growth, but the influence of external credit shocks and relative price shocks is also significant. The latter creates the possibility to determine various forces that contribute to an exchange rate collapse. Goldberg (1994) used data of the Mexican exchange rate regime between 1980 and 1986 and concluded that domestic credit shocks and relative price shocks play an important role in exchange rate crises. The influence of external credit shocks was relatively minor in the research of Goldberg (1994).

The studies mentioned above, however, provide only limited information on the extent to which the predictions of the theoretical literature fit the facts. Basically, all empirical studies used first generation models and no comparison was made with other type of models. The latter does not come as a total surprise since it is very hard to determine ex-ante expectations about the possibility of crisis induced policy change, needed to make estimations with second generation models. Furthermore, the empirical literature is mainly focused on a particular country at a certain point in time. Therefore, the general explanatory power of the first generation models is not really assessed, since not much is known about the representativeness of that country and the period that is covered. Further insight in the use of these models can be attained by analyzing a comprehensive set of crisis episodes and by comparing the relevant variables in crisis periods with their behavior during non-crisis periods.

### 2.4.2 Other empirical analysis of exchange rate crises

Some empirical studies, which do not necessary build on a theoretical model of speculative attacks, make intertemporal and bilateral comparisons of exchange rate crises that occurred in the past. Eichengreen et al. (1994) analyze speculative attacks on pegged exchange rates in 22 countries between 1967 and 1992. They develop stylized facts concerning the behavior of a variety of macroeconomic variables, comparing crises with periods of tranquillity. For non-EMS observations differences in behavior of fundamentals are found that are consistent with the predictions of first generation models. Budget deficits, inflation rates, rates of credit growth, and trade balances differ significantly between crisis and non-crisis episodes.

For countries in the European Monetary System (EMS), however, there are few significant differences found in the behavior of key macroeconomic variables between crisis and non-crisis periods. This could be interpreted as EMS crises being examples of self-fulfilling speculative attacks. However, the predictions of models with multiple equilibria in foreign exchange markets are also not confirmed for the EMS sub-sample. Thus, the limited relevance of the first generation models does not imply that second-generation models of self-fulfilling attacks necessarily fit the facts.

Frankel and Rose (1996) make an attempt to characterize currency crises in emerging markets. They try to determine stylized facts in a broad group of 'southern' countries and examine how much alike currency crises in developing countries are. They make a classification of four groups of variables that could be of influence on an exchange rate crisis. The first group consist of *foreign* variables such as 'northern' interest rates and production. The second group are *domestic* macroeconomic indicators, like output, monetary and fiscal shocks. Thirdly, a group of *external* variables is determined such as real exchange rate over-valuation, the current account and the level of indebtedness. The last group consists of variables expressing the composition of the debt of a country. The latter, for example, played an important role in the Mexican peso crisis of 1994.

Seven of the variables they examined are directly relevant to the speculative attack literature: the rate of growth of domestic credit (measure of monetary policy), the ratio of reserves to imports, the degree of real exchange rate over-valuation, the level of foreign interest rates, the growth of real output, the government budget as a fraction of GDP (measure of fiscal policy), and the current account as a percentage of GDP. The first four variables mentioned above seem to influence exchange rate crises as theoretically predicted. There is also a relationship between real output and currency crises, but the causality is unclear, since currency crises may either be caused by recessions or cause recessions themselves. Curiously, the last two variables mentioned above appear to be of no importance in explaining exchange rate crashes.

Sachs et al. (1996) analyze the reaction of 20 emerging markets to the multiple financial crises that occurred in 1995. They use economic fundamentals to help explain why some emerging markets were hit by crisis while others were not. They identified three factors that determine whether a country is more vulnerable to suffer a financial crisis: a high real exchange rate, a recent lending boom, and low reserves. They do not find support for alternative hypotheses that a high current account deficit, excessive capital inflows and loose fiscal policies help to explain the occurrence of exchange rate crises.

Furthermore Sachs et al. (1996) argue that the *Tequila effect*, the spread of a self-fulfilling panic across emerging capital markets, existed only partially. Only the previously weakened countries were hit by this effect. The 'strong' countries with plentiful foreign reserves or solid fundamentals, such as a not overvalued real exchange rate and a strong banking system, suffered no structural downturn in capital inflows. In

contrast, the countries with weak fundamentals and limited reserves relative to short-term liabilities were vulnerable to self-fulfilling investor panics.

Therefore, solid management of both the exchange rate and the banking system seems to be important in preventing currency crises. The problem is, however, that the policy consequences to achieve this goal are far less clear. Countries react very differently to large capital inflows, for example. Some countries experience strong real appreciation as result of the latter, where others depreciate in real terms and also the influence on domestic credit growth differs a lot between countries. According to Sachs et al. (1996) these different reactions might be caused by differences in fiscal policies and the differences in economic structure of these countries.

## 3. The model

### 3.1 A stochastic discrete-time model

Standard collapse models assume perfect foresight and rationality of economic agents. In combination with a situation where exchange rate is pegged, but has to be abandoned eventually as result of a steadily growing domestic credit stock, an exchange rate crisis is inevitable. The profit maximizing behavior of investors dictates that a strong speculative attack on the central bank's international reserves will occur at some point on the economy's path. This is an entirely rational market response to persistently conflicting internal and external macroeconomic targets.

The collapse model used in this paper is based on the discrete time model with uncertainty of Flood and Garber (1984b) and relies on money market equilibrium. The latter determines either the equilibrium exchange rate under a flexible exchange rate regime or the endogenous path of central bank reserves under a fixed exchange rate regime. In the standard model perfect foresight, uncovered interest rate parity and purchasing power parity are assumed. This model uses the concept of a 'shadow floating exchange rate' to determine the timing of regime collapses, which are entirely based on market fundamentals. The model is built around the following seven equations:

$$m_t^d - q_t = a_0 - a_1 i_t + a_2 y_t \quad (1)$$

$$q_t = \alpha p_t + (1-\alpha)(p_t^* + s_t) \quad (2)$$

$$p_t = p_t^* + s_t \quad (3)$$

$$i_t = i_t^* + (E_t s_{t+1} - s_t) + r_t \quad (4)$$

$$m_t^s = re_t + d_t \quad (5)$$

$$d_t = d_{t-1} + \mu_t + \epsilon_t \quad (6)$$

$$m_t^d = m_t^s \quad (7)$$

where $m_t$, $q_t$ and $y_t$ represent the natural logarithm of domestic money stock, the aggregate price level, and real national income and $i_t$ represents the nominal interest rate. $p_t$ and $p_t^*$ are the domestic currency price of domestic non-traded goods and the foreign currency price of traded goods. The terms $re_t$ and $d_t$ are respectively the logs domestic government book value of foreign money holdings and domestic credit. The log spot exchange rate, which is expressed as the domestic currency price of foreign money, is represented by $s_t$ and $E_t$ is an expectations operator at time t. The log of the country specific risk premium of the domestic currency is given by $r_t$ and a variable with an asterisks (*) is assumed to be 'foreign'.

The demand for real money balances is expressed by Eq.(1). Money demand is sensitive to: exogenously given real income, $y_t$, through transaction demands and the nominal interest rate, $i_t$, as a result of portfolio motives. Eq.(2) defines the aggregate price index as a weighted sum of non-traded goods prices, $p_t$, and the price level of traded goods $p_t^*+s_t$. The assumption of strict purchasing power parity is expressed by Eq.(3). Since in the standard model the influence of non-traded prices on the price level is neglected, resulting in $\alpha=0$, the aggregate price index is just equal to Eq.(3). When the model is extended later in the paper, the use of Eq.(2), together with the use of an alternative form of Eq.(3), becomes clear. Eq.(4) represents the linkage between the domestic and foreign interest rate. In the Flood and Garber (1984b) model interest rate parity was assumed, while here the interest rate spread is comprised of the (expected) change of the exchange rate and a risk premium. The money supply is defined in Eq.(5) and indicates that the high-powered money supply equals the book value of international reserves plus domestic credit. It is assumed that to finance government expenditure domestic credit grows at a rate $\mu_t$ and is occasionally hit by credit shocks, $\epsilon_t$, as is presented by Eq.(6). A difference with the Flood and Garber (1984b) model is the fact that domestic credit growth is no longer assumed constant. Instead domestic credit expansion is allowed to vary over time, therefore it is defined as $\mu_t$ in Eq. (6) in the model. The assumption of money market equilibrium is expressed by Eq.(7).

As before, a large expansion of domestic credit which is not absorbed by demand for real money balances causes disequilibrium in the money market. Equilibrium is restored in a fixed exchange rate regime by offsetting movements of the central bank's foreign reserves stock. With a fundamental disequilibrium, for example caused by systematic overvaluation, reserves are depleted and the central bank gets into difficulties. If agents initiate speculative attacks on the central bank's foreign reserves, they can fulfill their own expectations of an unsustainable fixed exchange rate regime by completely exhausting the stock of foreign reserves. This will cause the exchange rate to collapse and to float from there on.

To determine the endogenous path of the level of foreign reserves, the relationship between domestic credit creation and reserve depletion should be well understood. The demand for real money balances equation can be extended by filling in Eqs.(2), (3) and (4):

$$m_t = a_t - a_1(E_t s_{t+1} - s_t) + s_t \qquad (8)$$

where $a_t = a_0 - a_1(i_t^* + r_t) + a_2 y_t + p_t^*$, which is a constant if you assume the foreign interest rate, real income and the foreign price level to be constant in the short-run. A more extensive derivation of Eq. (8) and the rest of the model outcomes are given in appendix A1.

It follows from Eq.(8) that, while the exchange rate is fixed and, therefore, $E_t s_{t+1} - s_t = 0$, the demand for domestic nominal money balances is constant during the fixed exchange rate regime. In that situation reserve losses by the central bank are exactly matched by domestic credit expansion. This becomes more clear when the rate of change of reserves is determined. Together with the money supply equation and the money market equilibrium assumption, Eq.(8) transforms into an expression that states the quantity of reserves at time t in a fixed exchange rate regime:

$$re_t = a_t + s_t - d_t. \tag{9}$$

When the domestic credit variable is substituted by Eq.(6), the rate of change of international reserves becomes:

$$\Delta re_t = -\Delta d_t = - \mu_t - \epsilon_\tau \tag{10}$$

Money is constant but reserves are lost unit for unit as domestic credit expands. So, with a lower bound on net foreign reserves, after which the country will no longer defend the fixed rate, the fixed exchange rate regime cannot survive forever. The process will end with a discrete loss of reserves in a final speculative attack.

After the exchange rate collapse reserves are at their critical level ($re_t=r_c$) and, as follows from Eq.(5), $m_t=d_t+r_c$. The exchange rate is allowed to float freely and Eq.(8) can be rewritten as

$$m_t = a_t - a_1(E_t \tilde{s}_{t+1} - \tilde{s}_t) + \tilde{s}_t, \tag{11}$$

where $\tilde{s}_t$ is the post-attack flexible exchange rate, called shadow flexible exchange rate. To determine at what time T the exchange rate will collapse the floating exchange rate solution of Eq. (11) is needed. Remembering that $E_t\epsilon_t = 0$, using the method of undetermined coefficients and substituting the results into Eq.(11) the solution becomes:

$$\tilde{s}_{t+1} = (1+a_1)\mu_{t+1} - a_{t+1} + r_c + d_t + \epsilon_{t+1} \tag{12}$$

The shadow floating exchange rate does not depend on reserves. They are supposed to have reached their arbitrary minimum level, the critical reserve floor, after the collapse and are no longer used to influence the exchange rate. If the level of foreign reserves reaches this critical floor the monetary authorities will no longer use reserves to defend the domestic currency. Theoretically, $r_c$ can be positive or negative, because the central

bank could borrow foreign reserves internationally to keep the exchange rate regime from collapsing.

Speculators could profit from an attack by purchasing reserves at the controlled price $s_t^a$, the announced level of the exchange rate, from the monetary authority and reselling after the attack at the floating price $\tilde{s}_{t+1}$. If $\tilde{s}_{t+1} < s_t^a$ then speculators will not profit from this transaction, therefore not attack and the fixed exchange rate regime will survive. In the case that $\tilde{s}_{t+1} > s_t^a$ the speculators that purchase the reserves will reap a capital gain. The assumption of perfect foresight in this model, however, prevents luck to play a role. Competition between speculators ensures that the foreseen attack will take place at a moment when there are no profits or losses. The latter implies that the collapse will occur when $\tilde{s}_{t+1} = s_t^a$. Therefore, the probability of a collapse of an exchange rate regime in period $t$+1 is defined as the probability that $\tilde{s}_{t+1} \geq s_t^a$. Thus, the collapse probability is defined as follows:

$$\pi_t = \Pr[\tilde{s}_{t+1} \geq s_{t+1}^a], \tag{13}$$

where $s_{t+1}^a$ equals some pre-announced level of the controlled exchange rate and $\tilde{s}_{t+1}$ is the shadow floating exchange rate. Using Eq.(12) and assuming that $\epsilon_{t+1}$ represents a random disturbance with zero mean and which obeys $\epsilon_{t+1} = -1/\lambda + \nu_{t+1}$, whereby $\nu_{t+1}$ is exponentially distributed, the following expression for the collapse probability can be derived:

$$\begin{aligned} \pi_t &= \lambda e^{-\lambda K_t} && K_t \geq 0 \\ &= 1 && K_t < 0 \end{aligned} \tag{14}$$

where

$$K_t = s_{t+1}^a + a_{t+1} - r_c - d_t - (1+a_1)\mu_{t+1} + 1/\lambda. \tag{15}$$

and where variables dated in the future are expectations of those variables formed in period t and based on all available information in that period. The probability of an exchange rate collapse depends on the forecasts of agents on several economic values. The forecast of the variance of domestic credit, the rate of domestic credit expansion, the level of the critical reserve floor, the share of non-traded goods in the domestic price index, real income, the controlled exchange rate and demand for real money balances together determine the probability that a speculative attack will occur.

## 3.2 The extended estimation model

It is often believed that policies of the domestic fiscal authorities are only partial catalysts for speculative attacks on a currency. Therefore, Goldberg (1991a) relaxed the assumptions of the standard model and enabled the model not only to stress the importance of monetary and fiscal discipline, but also be influenced by other random shocks to the domestic money market. Most notable among these are shocks from external credit supplies and relative prices.

The reason for those extensions is that the collapse probability estimates generated by the standard model are understated to the extent that prices and external credit supplies exhibit short-term randomness. Collapse probability estimates could also be overstated if there are indeed non-traded goods in the domestic consumption basket, systematic deviation from PPP, and currency substitution motives in the demand for real money balances. Therefore, more realism is introduced adding these extensions to the model.

The first important modification is to account for the non-traded goods in the domestic consumption basket. Therefore, the deflation of the nominal money balances changes and the use of Eq.(2) becomes clear. No longer is the economy assumed to consist of traded goods only, which all are priced according to strict PPP, but the domestic price index is now defined as a weighted sum of the price of traded goods, $S_t P^*_t$, and the price of non-traded goods, $P_t$. Therefore, the share of consumed goods ($\alpha$) whose price is, at least partially, determined by domestic conditions and the share of traded goods ($1-\alpha$), which are priced according to the law of one price. In the model this means $\alpha$ is no longer assumed zero, but between zero and one. The deviation from the assumption of strict purchasing power parity (PPP) for all goods consumed domestically is expressed by a modified version of Eq.(3), which now becomes:

$$p_t - s_t = p^*_t + \rho_t + \Omega_t, \tag{16}$$

where $\rho_t$ denotes the medium-term systematic deviations from PPP and $\Omega_t$ expresses the stochastic shocks to relative prices. This deviation from strict PPP could lead to a situation with relatively costly domestic non-traded goods and potentially cheap exports.

Further, the influence of currency substitution motives on the demand for real money balances can be modeled. An additional term is therefore added to Eq.(1):

$$m^d_t - q_t = a_0 - a_1 i_t + a_2 y_t - a_3 (E_t s_{t+1} - s_t). \tag{17}$$

The last term in Eq.(17) expresses the influence the expected change in the exchange rate has on real money demand through the currency substitution motive. An expected future devaluation reduces the demand for the domestic currency now, because a possible capital gain can be made by holding foreign currency instead of domestic currency.

The model can be extended even more with a second additional equation to model the sources of domestic credit growth variability. The shocks to domestic credit creation are decomposed into two sources. Shocks related to unexpected domestic government revenues and expenditures and shocks related to the uncertain availability of external credit flows. Therefore, the residual of Eq. (6) is defined as follows:

$$\epsilon_t = \gamma_t - \phi_t, \tag{18}$$

where $\gamma_t$ is the random revenue or expenditure affecting the need to monetize the government deficit and $\phi_t$ the random availability of external credit. The latter term influences the share of government deficits that is financed by external borrowing instead of inflationary finance.

The shadow exchange rate is still defined as the exchange rate that would equilibrate the money market in the next period if reserves are depleted and the controlled exchange rate has collapsed. The shadow rate is derived in a similar way as above, only Eq. (18) is added to the model and Eq. (3) is replaced by Eq. (16). The equations from the extended model are combined to derive the new shadow exchange rate as:

$$\tilde{s}_{t+1} = (1+a_1+a_3)\mu_{t+1} - a_{t+1} + r_c + d_t + \alpha(\rho_{t+1} + \Omega_{t+1}) + \gamma_{t+1} - \phi_{t+1}, \tag{19}$$

where $a_t = a_0 - a_1( i_t^* + r_t) + a_2 y_t + p_t^*$ as before. The influence of relative price shocks on the exchange rate is negative, because real money demand for transaction purposes increases as result of a positive price shock. The relationship between external credit supply shocks and devaluation pressure is negative as well, because a positive shock to external credit reduces the need for domestic credit creation. Domestic government deficit shocks put upward pressure on the exchange rate, because this raises the relative supply of money balances through domestic credit creation.

The probability of a fixed exchange rate collapse in the next period is still equal to the probability that the expected post-collapse exchange rate will exceed the controlled exchange rate. Following the same solution methodology as before and assuming that $\Omega_{t+1}$,$\gamma_{t+1}$ and $\phi_{t+1}$ are distributed exponentially and have standard deviations of respectively $1/\lambda_0$, $1/\lambda_1$ and $1/\lambda_2$, the new collapse probability becomes:

$$\pi_t = \{\lambda_0\lambda_2/[(\alpha\lambda_1+\lambda_0)(\lambda_1+\lambda_2)]\}e^{-\lambda 1\, K_t'} \qquad K'_t \geq 0,$$
$$= 1 \qquad K'_t < 0, \qquad (20)$$

where

$$K_t = s_{t+1}^{a} + a_{t+1} - r_c - d_t - (1+a_1)\mu_{t+1} + 1/\lambda_1 - \alpha/\lambda_0 - 1/\lambda_2 \qquad (21)$$

and where variables dated in the future are expectations of those variables formed in period t and based on all available information in that period. The probability of an exchange rate collapse depends on the forecasts of agents on several economic values. The forecasts of variance of relative prices, the variance of domestic credit, the variance of external credit supplies, the rate of domestic credit expansion, the level of the critical reserve floor, the share of non-traded goods in the domestic price index, real income, the controlled exchange rate and systematic overvaluation of the non-traded goods determine together the probability that a speculative attack will occur.

### 3.3 Second generation model

The effects of the points stated above can be shown in the standard model. In the model above it is assumed that the central bank will not sterilize the reserve loss at the time of the attack. However, when this assumption is dropped and it is assumed that reserves are fully sterilized at the time of collapse the situation changes. The alternative assumption is made when, so called, second generation collapse models are used. The standard model becomes inconsistent with a foreseen attack when the assumption of a policy switch is used. The collapse takes place at the moment of interception between the fixed rate and the shadow floating rate, but now the authorities fully sterilize the reserves losses and speculators earn a capital gain as result of a discrete jump of the exchange rate. As a result of full sterilization the discrete adjustment in the base money supply, caused by reserve depletion, is removed. However, there is still a discrete jump in the money demand due to a shift in the domestic interest rate. The imbalance between supply and demand makes it impossible for the fixed exchange rate to survive when the central bank switches policy after an attack. If the central bank makes this policy switch, the post-collapse flexible exchange rate in Eq.(12) becomes

$$\tilde{s}_{t+1} = (1+a_1)\mu_{t+1} - a_{t+1} + r_c + d_{post,t} + \epsilon_{t+1} \qquad (22)$$

where $d_{post,t}$ measures domestic credit just after the collapse. The latter is very important, because d jumps upward at the time of the attack as result of reserve sterilization. It follows that $d_{post,t}$ is equal to the pre-attack base money supply. Also it indicates that

$\tilde{s}_{t+1}$ is always greater than $s_{t+1}^{a}$ after the collapse. This means that a fixed exchange rate with full sterilization of reserve losses in a collapse will be attacked immediately.

The policy switch made by the monetary authorities makes the speculative attack self-fulfilling. *Ex post* the attack on the currency is justified by the discrete jump of the exchange rate as a result of the full sterilization of the reserve losses. Note, however, that the speculative attack is self-fulfilling conditional on the policy switch. If the monetary policy is unaltered, the exchange rate will not jump and no capital gain can be made by the investors.

Once again this shows how important credibility of government policy is with respect to fixing the exchange rate. One can imagine how much more difficult it becomes to manage an exchange rate as soon as expectations are formed of a policy switch after a currency is attacked. Even if the post-attack policy switch is uncertain, there still will be a lot more speculative pressure against the currency and the volatility of the exchange rate will probably increase as well. Building a reputation as an reliable policy maker helps reducing this kind of speculative foreign exchange pressure and increases the possibilities to stabilize the exchange rate with respect to an other currency.

# 4. The Mexican peso crisis of 1994

## 4.1 Background

The collapse of the Mexican peso in December 1994 was the sixth time an exchange rate crisis occurred in Mexico since 1945. All previous collapses created similar effects in the economy. All of them were preceded by economic expansion, sharp real appreciation, and large external deficits. Since 1976 these crashes all came just after presidential elections. However, to understand the specific elements of the '94 peso crisis that do not fit the previous crises the economic conditions in the preceding period have to be described.

At the end of the 1980's the Mexican government introduced an exchange rate based stabilization plan to increase economic growth and bring down triple digit inflation rates. The stabilization plan formally started in December 1987, while the exchange rate was put in an adjustable narrow band on February 29, 1988. The history of the exchange rate policies in Mexico in the 1988-1994 period is presented in table 1. The key component of the stabilization plan was a social agreement or 'pact' which forced workers, firms, and the government to meet regularly and determine together price, wage, and exchange rate policies. The plan was further accompanied by large structural reforms that were initiated 1984. The response of the economy was typical for exchange rate based stabilizations. An economic boom was initiated, the real exchange rate appreciated, and the current account deficit increased.

The structural reform implemented by the Salinas government was a far reaching program that restored fiscal and monetary discipline. The import substitution approach was replaced by aggressive trade liberalization, which consisted of joining GATT in 1986, a strong reduction of non-tariff barrier coverage and a fall of the tariff range to 0-20%. The outward growth strategy was further supported by the trade stimulating effects of the North American Free Trade Agreement (NAFTA). Also a major privatization program, together with liberalization and deregulation of several industries, was initiated. Small manufacturing firms were privatized first, public utilities next, and after that banks followed. By 1994 approximately 80% of state owned enterprises had been privatized. Oil related firms, however, remain government owned until present day. Further, a tax reform started in 1985 and a large fiscal adjustment was accomplished. A primary deficit of around 6% of GDP was transformed into a surplus of approximately 7% of GDP.

Finally, an important financial reform was initiated in 1988, when interest rates were freed. The privatization of banks gradually took place after 1990 and they were allowed to hold equity positions in manufacturing and other firms. However, some directed credit and subsidized loans were still handled by development banks. The

regulatory and supervisory capacity of the banking sector remained weak. All of this led to a situation were, by late 1993, there were no signs of most of the familiar symptoms of exchange rate based stabilization plans. Expansionary policies and falling foreign reserves, both typical of near crisis situations, were not present. The inflation rate was reduced from 159% in 1987 to 7% by 1994 and accompanied, as noted before, by a strong restrictive monetary policy in the 1988-1994 period and attainment of fiscal balance.

*Table 1: Exchange rate policy in Mexico 1988-1994*

| | |
|---|---|
| February-December 1988 | Fixed nominal exchange rate at 2281pesos per dollar. |
| January-December 1989 | Preannounced rate of devaluation set at 1 old peso per day. |
| January-December 1990 | Preannounced rate of crawl of nominal exchange rate at 80 cents per day. |
| December 1990-November 1991 | Preannounced rate of crawl of nominal exchange rate set at 40 cents per day. |
| November 1991-October 1992 | Exchange rate band adopted. Floor is fixed at 3050 pesos per US dollar, while ceiling slides at 20 cents per day. |
| November 1992-December 19, 1994 | Rate of devaluation of band's ceiling is accelerated to 40 old cents or 0.0004 new pesos per day. |
| December 20-December 21, 1994 | Ceiling of band increased by 15 percent. |
| 34689 | Floating exchange rate adopted. |

However, the performance of the Mexican economy between 1988 and 1994 was, in spite of the reforms, rather modest. Real growth averaged 2.8% and there was practically no productivity growth until 1993. There was a strong appreciation of the real exchange rate, export expansion was not very impressive, private savings declined heavily and poverty and income distribution continued to be a major problem.

The largely unimpressive economic results of Mexico were contrasted by the outstanding achievements of policy reform. In spite of this divergence, the (inter)national media, financial experts, academics and multilateral institutions consistently considered Mexico a major success. The faith in market oriented reforms led many analysts to believe that if economic results were not there yet, they were

waiting around the corner. Also, the alleged benefits of NAFTA contributed to the popular notion that the Mexican economy had very good future perspectives. This optimism was further expressed by the large net capital inflows into Mexico that took place from the beginning of the ‘90's .

Therefore, a large financial crash, as occurred late 1994, was not expected. The economic ‘fundamentals’ were sound and a potential devaluation was expected to cause a realignment of the real exchange rate and, thereby, a reduction of the current account gap. It was believed the latter would by followed by a widely expected economic take-off from the Mexican economy, not to bring about a reduction in production and a nation wide recession.

### 4.2 Real exchange rate appreciation and foreign capital flows

As often stressed in the literature (Kamin and Rogers (1996), Calvo and Mendoza (1996)) a lot of failures to maintain a (quasi) fixed exchange rate are not the result of conflicting macroeconomic policies, but rather an outcome of developments, such as real appreciation and a current account deficit, endemic to exchange rate based stabilization programs. These developments, in turn, undermine the sustainability of the fixed exchange rate regime. Therefore, the main factors that led to the collapse of the Mexican peso are present in almost all exchange rate based stabilization programs. Almost all Mexican exchange rate crises show this pattern.

To the extent that inflation exhibits some degree of inertia, stabilization programs based on an exchange rate anchor have the danger of generating a significant real exchange rate overvaluation, a loss of competitiveness, and very large trade deficits. If such a situation is not corrected in time, the credibility of the stabilization program will be called into question and speculative attacks on the currency can be expected. The Mexican authorities argued, however, that there were four reasons why the latter would not happen in Mexico. First of all, the stabilization policy was started from a situation of undervaluation. Secondly, the large stock of international reserves of Mexico. Thirdly, the supposed rapid growth of productivity that would compensate for the real appreciation of the peso. Finally, the increased capital supply as result of NAFTA and the new opportunities to rapidly develop exports offered by this free trade agreement.

In reality, however, the decline of the inflation rate was painfully slow in the beginning of the stabilization program, the real exchange rate appreciated substantially and the stock of foreign reserves declined as result of financing of the rapidly growing trade balance deficit. However, after the 1990 Brady debt reduction agreement and the beginning of opening the financial sector and privatization of banks, the international capital market rediscovered Mexico. This resulted in a surge of capital inflows that allowed the country to finance very large current account deficits in the 1992-1994

period and to maintain, for at least some time, an overvalued real exchange rate. Most of these funds flowing into Mexico after 1990 were portfolio flows invested in the stock market, in private sector instruments, and in government securities. The composition of these flows, specifically their short term nature, added to the vulnerability of the system as a whole.

Another disturbing development was the steep decline in private savings after 1989. This contrasted sharply with the experience of most East Asian countries during the early 1990's. The capital inflows in these countries resulted in significant increases in investment rates. After 1993 the drop in saving became even more serious, as fiscal policy was relaxed and public savings also experienced a decline.

The Mexican authorities responded to these problems by emphasizing that the situation was not worrisome since the flows into the country were largely private and the fiscal account was in surplus. They had three basic arguments to defend this vision. First, the economic system of the country had enough built-in flexibility, resulting from flexible interest rates and the operation of the exchange rate band, to deal with eventual disequilibria. Second, a rapid increase in productivity, that would generate a major export expansion, was about to take place. Third, the long term fundamental values remained healthy.

One of the things the authorities neglected was that the rate at which capital was flowing in, which was approximately two times the rate of real GDP growth, was not sustainable in the long run. At those rates of capital inflow the volume of Mexican securities held by foreigners as a proportion of the country's GDP would tend to grow continuously. Therefore, the real appreciation induced by the greater availability of foreign funds was clearly a short term phenomenon that had to be reversed, at least partially, sometime in the future.

At that time a serious problem was born. Once the capital stops flowing in, or even when the rate at which it flows slows down, the real exchange rate will be overvalued and a massive adjustment will be required. However, while during the surge in inflows the real exchange rate will increase without any impediments, when the availability of foreign capital flows declines, the nominal wage and price rigidity will make the required real depreciation difficult. Mexico's commitment to the rigid exchange rate system, the obsession with single digit inflation and a succession of negative shocks to the economy made the possibility of a smooth landing increasingly unlikely during the year 1994.

The vulnerability of the financial sector and the monetary authorities to international capital flows is also expressed by Calvo and Mendoza (1996). They present two indicators of financial vulnerability that signal the possibility of an exchange rate crisis driven by a run against domestic assets. First, the gap between money (M2), valued in US dollars, and gross foreign reserves. Where, not so much the size of the gap, but the

risk of a sudden and large shock to the money stock is dangerous. The latter can imply a large drain of foreign reserves and, therefore, put the controlled exchange rate under pressure. Therefore, it is the instability of the ratio between money and foreign reserves that poses a threat to the exchange rate regime. Analysis of the determinants of the money stock in Mexico after the financial liberalization from 1988-1989 (Calvo et al. (1993), Calvo and Mendoza (1996)) shows a strong influence of international capital flows on M2. This indicates the increased vulnerability of the Mexican economy to international capital flows.

The second indicator of excessive vulnerability is the gap between short-term public debt (peso- and dollar-denominated) and foreign reserves. A large short-term debt-reserves imbalance (debt>reserves) developed in the 1993-1994 period. This imbalance ended with collapse of the peso, which occurred when the dollar-denominated short-term debt could no longer be rolled-over. Just before the crisis the short-term public debt was nearly three times larger than foreign reserves. This large imbalance was the result of an overexpansion of central bank domestic credit. After the Colosio assassination a run against peso-denominated debt by banks and the private sector resulted in a large reserve loss. The monetary authorities responded with sterilization of the effect on the monetary base by expanding domestic credit. Further, they began issuing dollar-denominated debt and thereby initiated dollarization of public debt. In principle, the reserve losses could have been limited by sufficiently large monetary contraction, but the sterilized intervention prevented that from happening and thereby caused a large loss of foreign reserves.

In general the indicators of Calvo and Mendoza (1996) show how delicate the situation in the banking sector was in 1994. The financial reforms and the foreign capital inflows from the preceding years contributed to a large increase in the supply of loanable funds. The controlled exchange rate gave an incentive to disregard exchange rate and country risk for investments, because the latter were implicitly transferred to the central bank. As the banking sector weakened, agents realized the intent to commit effectively to the controlled exchange rate regime compromised the ability of the central bank to act as lender of last resort. The central bank had to choose between protecting the banking system using sterilized intervention, which leads to weakening of the currency, or tighten monetary policy to support the exchange rate regime and risk the bankruptcy of commercial banks.

In spite of this situation, it is often argued (Atkenson and Rios-Rull (1996), Sachs et al. (1996)) that the Mexican monetary policy did not react forcefully enough to the problems that arose in 1994. However, it must be noted here that the growth of the money stock was not necessarily the result of shocks in the money supply, but could have reflected shocks to the demand for money. Kamin and Rogers (1996) find empirical evidence that the Mexican monetary policy was not significantly looser in 1994 than in the period preceding it. They point out that the monetary authorities

reaction function did not change, because the monetary policy was not significantly looser in 1994 than implied by an estimated monetary policy reaction function. This view is supported by the fact that interest rates rose in 1994, while an expansion of the money supply would depress interest rates.

This does not mean that the interest rates were sufficiently high to prevent a devaluation. To raise interest rates even more a monetary policy switch would have been needed. At the beginning of 1994, however, monetary authorities were highly concerned with the health of the Mexican banking system and the low level of economic activity. In these circumstances it is not surprising that the authorities chose to allow interest rates to rise moderately, in spite of the fact that such a limited reaction to foreign exchange developments caused large declines in the stock of reserves.

### 4.3 1994: the year of crisis preparation

Although the accumulated disequilibria and the slow growth in productivity created a vulnerable situation, the market was still very enthusiastic about Mexico at the end of 1993. The approval of NAFTA was of major importance in creating this positive view. However, when on January 1 of 1994 the *Zapatistas* army started an uprising in the southern state of Chiapas, the first signs of trouble became clear. The uprising was an obvious signal that Mexico was still a country with pressing social problems and large inequalities. As a result of the increased political uncertainty this created, the exchange rate shot up to the upper limit of the band in late February 1994. Surprisingly, however, the domestic interest rates, the stock of reserves and the capital inflow were hardly negatively influenced by these circumstances and by mid March it seemed that things were under control again.

All of this changed when the presidential candidate of the ruling party, Luis Donaldo Colosio, was assassinated while greeting a crowd at a political rally in *Lomas Taurinas* in the state of *Baja California*. This time there was indeed a negative reaction by the financial community and foreign and domestic investors reduced their demand for Mexican securities. The exchange rate was allowed to depreciate to the top of the band, the fiscal policy was not tightened and an eventual depletion of reserves became increasingly likely. The latter was caused by the fact that the current account deficit would inevitable grow as a result of currency overvaluation and the resulting gap could not be financed by financial inflows from abroad. All of this led to strong intervention in the capital market by the monetary authorities and an increase of peso denominated interest rates from around 10 percent in February to more than 16 percent in April.

Additionally, Mexico experienced difficulties rolling over its rapidly maturing peso denominated debt. In April the decision was made to impose a cap on peso denominated interest rates and the substitution of dollar linked securities, *Tesobonos*, for the maturing

peso denominated debt was initiated. The risk of future currency devaluation now was much more shouldered by the Mexican government, since the new debt was denominated in US dollars and investors were no longer harmed by a future devaluation of the peso.

At the same time the government resisted increasing interest rates on peso denominated public debt, the central bank sterilized the decline in reserves. The decision to maintain the money supply target unaltered implied a decline in reserves that had to be compensated with increases in central bank credit. This allowed for important increases in domestic credit by the financial system. On top of all this, the government decided to relax fiscal policy as a response to a political campaign that turned out to be unexpectedly difficult.

During the first half of 1994 concerns among international analysts on the sustainability of Mexico's external situation grew. Dornbusch and Werner (1994) argued that the Mexican peso was overvalued by at least 30 percent, and that the authorities should rapidly find a way to solve this problem. They stated that a real exchange rate realignment should take place, either through an accelerated crawl of the nominal exchange rate or even a floating nominal rate. However, Calvo (1994) argued that any exchange rate adjustment was likely to generate a financial panic, because of lack of credibility. Therefore, he stated that the solution lay in regaining credibility by obtaining massive support from the U.S. Treasury.

Between April and October foreign reserves and peso denominated interest rates remained stable. The nominal exchange rate rose to the ceiling of the band, but remained within the target zone. It should be kept in mind that this period of relative stability was accompanied with a government policy of increasingly replacing of peso denominated debt by Tesobonos, thereby rapidly changing the currency composition of broad money (M3). By August the amount of Tesobonos outstanding was roughly equivalent to the stock of foreign reserves.

In August Dr. Ernesto Zedillo Ponce de Leon was elected President. After an active policy debate the Pacto was renewed once again in September, without the introduction of major policy changes. The exchange rate, monetary and fiscal policies remained the same and the substitution of Tesobonos for maturing peso denominated debt was continued. The lack of government action and growing uncertainty made investors become nervous. In November some investors decided to reduce their exposure in Mexico, largely as result of uncertainties linked to the inauguration of the new administration in December. The central bank kept on sterilizing all the reserve losses. By the end of November reserves stood at $12.5 billion, while short-term public debt was in excess of $27 billion. The situation started to develop all the characteristics of a major financial crisis, since the reserves of the central bank clearly had become insufficient for backing short-term domestic public debt.

The decline of foreign reserves that started in November continued into December. On December 20th, when reserves reached dangerously low levels, the authorities opted for a change in policy. The exchange rate band was widened and the peso was allowed to devaluate for 15 percent. However, the widening of the band was not accompanied by a supporting program and the authorities did not specify how they would handle a possible massive withdrawal of deposits. Investors reacted disappointed to the ineffective effort to make a policy change and fled away from Mexican securities. Two days later, the controlled exchange rate collapsed and the peso had to be floated.

## 4.4 Policy lessons for controlled exchange rate management

### 4.4.1 Reform programs and balance of payments sustainability

The Mexican experience makes it also very clear that unsustainable trade deficits, which are financed by large foreign and highly volatile capital inflows, should be avoided. In 1991 the international capital markets rediscovered Mexico. The resulting large capital inflows allowed the country to finance very large current account deficits in the 1992-1994 period. The Mexican officials argued that this large increase in capital inflows was generating an 'equilibrium' real exchange rate appreciation. In their point of view the strengthening of the peso was fully justified by fundamental values.

In addition to allowing an unsustainable current account deficit to emerge as result of the real appreciation, two more remarks should be made about the Mexican current account financing. First of all, the most important component of the capital inflows was short term portfolio investment. Secondly, in other countries investment was stimulated by the large current account deficit, while in Mexico a significant decline in savings took place. The short term nature of most capital inflows added to the volatility of the Mexican economy, while the substitution of domestic for foreign savings limited the growth possibilities and made overall economic performance highly dependent upon financial resources of a highly unstable nature.

The official point of view of the Mexican authorities was that with the fiscal accounts under control, there was no reason to worry about the current account deficit being financed by private capital. The Mexican crisis showed clearly that this argument is not correct. Even if the current account is financed privately, when it becomes too large an adjustment will eventually have to be made. A reduction in aggregate expenditure will be needed in combination with a relative price adjustment or a real exchange rate devaluation. In a controlled exchange rate system such a realignment will require a drop in nominal prices of domestic goods and wages and will cause political and social resistance against these adjustments.

Like with most successful stabilization programs, which are based on fixed nominal exchange rates, a private sector consumption boom was generated in Mexico. To keep the current account under control the latter generally requires high public savings to offset the decline in private savings. Relatively little is known about the best way to raise private saving rates, but institutional reforms that stimulate private saving are likely to be needed to help solving the problem of low savings. Furthermore, the financial system should be made efficient, dynamic and especially sound to increase confidence in the total economic system and to stimulate private savings as well.

An other possibility to reduce the disruptive influence of capital inflows is to limit the liberalization process of capital controls in the early stages of a reform program. It is still an ongoing discussion whether the opening of the capital account should take place early on in the transition process or whether some form of impediments to capital mobility should be retained until trade liberalization is complete. The line of reasoning behind this argument is that liberalization of the capital account, under some conditions, will lead to large temporary capital inflows, which will cause an appreciation of the real exchange rate. The latter decrease international competitiveness and will frustrate a rapid expansion of exports.

Therefore, the debate in the international literature now mainly focuses on the most adequate sequencing and speed of liberalization and stabilization reforms. In this discussion it is of great importance whether highly volatile short term capital is dominant in the capital inflows or whether those inflows are dominated by foreign direct investment (FDI). If the latter is the case the degree of vulnerability of the economy for capital inflows is greatly reduced.

If volatile short term investment is dominant, however, it might be beneficial to spread the capital liberalization through time and allow foreign capital gradually into the country. This gradual adjustment can be achieved through the use of several instruments, such as smaller fiscal deficits, the slow removal of capital controls or the discouragements of short term capital inflows. However, two more remarks should be made on this subject. First, the existence of capital controls will not completely solve the problem of real exchange rate appreciation and, second, capital controls should only be used as a transitional device. In the long run, impediments to capital mobility should be dismantled and the country should take full advantage of the opportunities offered by world capital markets.

### 4.4.2 Exchange rate policy

One of the most important things to take care of is to make sure the exchange rate policy is credible in the long-run. As mentioned before, for an exchange rate policy to be credible it should be supported by fiscal en monetary policies that assure the

maintenance of the fixed or controlled parity between to currencies. Prudent government policies have to be implemented and kept in place, even if politically difficult circumstances arise as result of real exchange rate realignments.

After the Colosio assassination in March 1994 the inflow of foreign capital decreased and a policy change was needed. However, the Mexican monetary and fiscal policies were not contractionary enough and the nominal exchange rate rose to the top of the band. According to Sachs, Tornell and Velasco (1996) a devaluation of the peso at that time by lifting the ceiling of the currency band and at the same time following tighter monetary an fiscal policies could have prevented 1994 crisis with high probability.

Opponents of such a surprise devaluation stress the credibility costs associated with such a policy. Hard won government credibility will be lost and faith by the public that policy makers will follow non-discretionary policies will be lost. Sachs, Tornell and Velasco (1996) argue that this argument is correct, but not complete. The public's confidence in the controlled exchange rate regime is not only influenced by the government's commitment to this policy, but also on the ability to sustain the regime given the external circumstances. By letting the stock of reserves decrease rapidly the government showed commitment to the policy of not devaluing, but increased the likelihood that the exchange rate regime could not be sustained. The latter is true because expected devaluation is the product of two terms: the probability of a devaluation taking place times the size of the specific devaluation. Therefore, it could well be that a discrete devaluation in March 1994 would actually have decreased rather than increased the expected rate of devaluation of the public.

### 4.4.3 Macroeconomic policy

One of the theoretical arguments for good fixed exchange rate management, that has been proven right by the Mexican peso crisis, is that consistency between different macroeconomic policies is needed to make an exchange rate regime sustainable. When a country is confronted with large capital inflows it faces two possibilities: to sustain the nominal exchange rate by having the central bank purchase the foreign exchange or to allow the nominal exchange rate to appreciate. Under a controlled exchange rate regime, the latter is not an option and the only remaining question then becomes whether or not to sterilize the purchase of foreign reserves made by the central bank.

The convenience of performing monetary sterilization is a matter of debate when money is flowing into the country. This is because the monetary contraction as result of sterilization will imply fiscal costs for the central bank and might, through producing an increase in interest rates, turn out to be a partially self-defeating proposition. When money is flowing out of the country, however, it is generally acknowledged that sterilization of the decline in reserves should be avoided. Sterilization would put

downward pressure on the exchange rate and under fixed exchange rate regime will cause the excessive domestic credit creation to translate into a movement in opposite direction in the stock of international reserves. Most analysts believe the Mexican reserve sterilization in 1994 to be a major policy mistake.

In these matters it is very important to have a reliable assessment of what is happening in terms of money demand. Even though it is reasonable, it does not always have to be the case that the money demand is falling in the presence of an adverse political shock. A policy of not sterilizing a reserve decline when money demand has actually not decreased might cause a rise in interest rates. Obviously, the argument can be stated the other way around as well. The point is, however, to show the importance of closely monitoring and analyzing the behavior of the money demand when managing a controlled exchange rate.

This management is particularly difficult when the system does not allow for enough exchange rate flexibility. In the extreme case of completely fixed exchange rates, the changes in international reserves will lead directly to monetary contraction or expansion and, therefore, to changes in the domestic interest rate. This means that faced with a capital outflow, the sustainability of a fixed exchange rate is closely linked to the authorities' willingness to allow for high interest rates. High interest rates generally lead to increases in unemployment and falling output and are, therefore, not very popular among policy makers.

### 4.4.4 Central Bank independence

In political life it seems to be very difficult to make credible policy commitments and therefore a lot of countries endowed their central banks with independence from the government. This means central bank authorities are appointed for periods of time that differ in time and termination date from that of the government. The idea is that an independent central bank will not be subject to the pressures of the political cycle and will not be tempted to abuse its power to print money and let inflation rise. This institutional arrangement creates a situation where the central bank establishes policies that strive for long-term stability and not for short-term gains. Given this long-term appointment and the fact that the central bank values reputation, an independent bank can commit itself in a credible manner and is able to produce policies that are welfare improving when compared with other discretionary policies. Therefore, one could argue that independent central banks are not a sufficient condition to achieve macroeconomic stability, but they are a very important complement to macroeconomic policy in many cases.

The central bank of Mexico, Banco de Mexico, was granted independence in April 1994. The policies they designed, however, did not really express the independence one

would want from a credible central bank. Especially the decision to sterilize the decline in reserves after March, while the exchange rate was still fixed, is rather puzzling. Alternative policies could have been either an early allowance for flexibility in the exchange rate system in March or April or defending of the fixed exchange rate with a much more restrictive monetary policy. The latter policy would have reduced economic growth, while the former policy would influence the price level. As mentioned before, the unhealthy situation of the banking system complicated the policy decisions considerably. Both alternative policies spelled trouble for the government, especially given that 1994 was an election year. Finally, the central bank acted in a way that one would predict of an elected government in an election year: they kept selling reserves and postponed the exchange rate adjustment as long as possible.

All of this makes it very clear how important it is to have a truly independent central bank. Maybe even more important, it shows that institutional changes are much more easily done on paper than in practice. The Mexican experience points out the fact that it is important to accompany a process of economic reform with meaningful and structural institutional changes.

### 4.4.5 Debt management

One of the most important lessons to be learned from the 1994 peso crisis is the importance of domestic public debt management. By definition the increase in public debt is equal to the seize of the fiscal deficit and, therefore, stabilization of the stock of public debt is attained by achieving fiscal balance. However, even if the stock of public debt is stabilized, it still has to be rolled-over. The Mexican crisis showed that the conditions under which the public debt is rolled-over are of crucial importance. The problem is that these conditions change over time and that governments might be confronted with very unfavorable refinancing conditions and, as result of that, increasing financing costs. To tackle these kind of problems government might choose to use temporary devices that do not fundamentally solve the problematic situation. Shortening of debt maturity and refinancing of the debt in a foreign currency are good examples of such measures and both were applied in Mexico.

In early 1994 Mexico was hit by both internal and external shocks and the rolling-over of the public debt became increasingly difficult. In order to maintain the term-structure and currency composition of the financing sources, very high interest rates would have been necessary. The authorities pretended to resist this outcome by significantly changing its domestic debt policy. This change consisted of replacement of peso-denominated debt (Cetes) by dollar-denominated debt (Tesobonos), while at the same time the importance of long-term bonds in domestic public debt gradually declined.

The important point to be made here is that although the traditional measures of fiscal policy, primary and operational balances, had deteriorated only a little, the composition of the debt stock was developing in a most unfavorable and unsustainable way. Most investors and analysts did not understand the significance of these developments, where they should have been interpreted as clear signs of distress. Therefore, in the future much more attention should be given to monitoring the development of the currency and maturity structure of public debt. Abundant purchases of domestic currency-denominated long-term debt might reflect market confidence on the stance of the complete macroeconomic policy. The complete opposite is true if investors only want to purchase short-term foreign currency-denominated bonds. Such a signal should be interpreted as a warning sign and used as indicator for the development of alternative fiscal and monetary policies.

### 4.4.6 Financial sector structure

In the process of transforming capital inflows into increased financing and higher expenditure the financial sector plays a crucial role. This also means, however, that the financial sector can be very dependent on these capital flows. A reduction or reversal of capital inflows can cause significant problems to the banking system and will feed back new problems into an already complicated macroeconomic environment.

The deep rooted problems in the Mexican financial system became very clear after the collapse of the exchange rate and to a great extent they were responsible for the unexpected severity of the Mexican peso-crisis. The contraction in output, as a result of an exchange rate crisis, has been much more significant than most pessimistic analysts had expected and many analysts blame the unhealthy situation of the banking system at the outbreak of the crisis for this.

Between 1991 and 1992 the Mexican government privatized 19 banks that had been nationalized as result of the debt crisis. At that time the need to develop an effective regulatory framework for the banking sector was acknowledged, but Mexico experienced that it is not so easy to effectively and rapidly create a solid regulatory framework. The lack of trained personal, like inspectors and accountants, and the rivalry between different government institutions with overlapping responsibilities slowed down the process. At the time of the exchange rate collapse in December 1994, the supervisory system was still seriously underdeveloped and the banking sector was in a rather weak position. Concerns regarding the strength of the financial system probably also influenced the decision to strive for low interest rates in spite of the exchange market pressure against the peso. In the end, macroeconomic problems and financial sector weaknesses fed into each other, making a bad situation even worse.

## 4.5 Résumé on the Mexican peso crisis

The Mexican peso crisis of December 1994 raised some questions about the sustainability of the reform programs applied in Latin America. Some people argued that this crisis was an indication that Latin American were not yet ready for the market-based transformations. In reality, however, these concerns seem to be groundless. The crisis has provided a boost to the modernization and reform oriented process in Mexico. The crisis made it clear to policy makers, intellectuals and a large share of the public that a reform process never ends and that there still were some urgent unfinished tasks. The urge to reform the economic, political and social system increased during the crisis in 1995 and in the 1995-1997 period some serious progress in reforming the financial sector and making the political system more democratic has been made.

In recent literature (Calvo and Mendoza (1996), Sachs, Tornell and Velasco (1996)) it is often argued that imperfect credibility of Mexican exchange rate policy in combination with highly liquid global capital markets contributed a lot to the 1994 peso-crisis. It could well be that self-fulfilling expectations generated a panic after it became obvious the government was running down its gross reserves and ran up short-term dollar debt.

The large devaluation and the severe recession that followed showed the vulnerability of exchange rate regimes to shifts in foreign capital flows, despite the tight policies pursued in 1988-1993. However, the strongly increased integration and mobility of international capital markets in the last decade, caused poorly managed capital inflows and large imbalances between stocks of liquid financial assets and gross reserves. This did not only evoke a devaluation, but also initiated a massive run against domestic assets as result of a panic from investors.

Calvo and Mendoza (1996) argue the abrupt change of mind on the advantages of Mexican investments by international investors can be explained by standard portfolio diversification motives, but not as result of a sudden change of investors prospects on Mexico's fundamentals. The speculative attack against the peso and the spill-over of the peso-crisis into emerging stock markets worldwide (*tequila effect*) is better understood in a context where the growth of the global capital market reduces the gains from information gathering and leads to herding behavior of investors. This occurs because world wide and highly diversified investors have lower incentives to collect information than investors with less investment opportunities. The marginal benefit from information gathering eventually declines, when the number of countries to invest in rises. In such situations it becomes possible that the equilibrium response to news is a self-fulfilling panic.

The sudden dumping of Mexico's assets by international investors could have been such a panic, originated from a small negative change in profitability expectations. The

initial devaluation could have altered those expectations slightly, because it signaled a reduction in reliability of the new government. However, it should be noted that this argument can not explain why the situation did not stabilize after the drop in stock market prices, which should have restored profitability of domestic assets.

Sachs, Tornell and Velasco (1996) argue that the Mexican peso crisis is better understood when the possibility of a self-fulfilling panic is accepted. After the government had run down gross reserves and accumulated large amounts of short-term debt self-fulfilling expectations generated a panic. This panic might have been prevented if credibility of the exchange rate regime had been increased by following a more contractionary fiscal and monetary policy in 1994. The latter doesn't mean that the '94 peso crisis was a '*death foretold*' or a situation were the economy is on an unstable course as result of inadequate policies and external shocks. According to Sachs, Tornell and Velasco (1996) the quite conservative fiscal policy, the relatively modest level of debt ratios and interest rates just before the crash made it by no means clear that an exchange rate collapse was inevitable. In their view, it was the announcement of a 15% devaluation in December 1994 that caused a shift to a self-fulfilling panic equilibrium.

The Mexican crisis showed the importance of reducing the dependence on foreign highly volatile portfolio investment, raising the level of savings to allow for adequate levels of investment and to continue reforming the financial system by implementing modern regulatory systems. Additionally, the crisis illustrated the difficulties of maintaining a controlled exchange rate system for long periods of time. The short term benefits of stabilizing expectations and imposing fiscal and monetary discipline can be confronted in the long run with the problems of an overvalued real exchange rate.

However, the way Mexico reacted to the 1994 peso-crisis is rather promising. The people in Mexico remained reform oriented, some necessary reforms were already made since the economic structure is largely healthy, the economy is growing again, public finances are still under control, the financial sectors are being strengthened and the exports sector is becoming a growing and dynamic sector. All of this makes it also possible that international confidence in Mexico is slowly being rebuilt. The latter is also caused by the fact that there is a strong economic basis and a lot of political willingness in Mexico to address the challenges that lay ahead.

# 5. Empirical research

## 5.1 Data description

The empirical research was done with monthly data for the period of 1988 through 1996. In total data from nine countries was used (Mexico and the US plus seven European countries that participated in the EMS) and sometimes smaller sample periods had to be chosen as result of lack of data availability. Unless otherwise indicated the data were drawn from the cd-rom version of *International Financial Statistics (IFS)*. For Mexico the exchange rate regime relative to the US dollar was analyzed, while for the European countries the exchange rate regime relative to the German D-mark was studied.

The following time-series from IFS were used as variables in the model: short-term money market interest rates (line 60b in IFS), international reserves (line 11), domestic credit (line 32), consumer prices (line 64), wholesale prices (line 63), real GDP (line 66) and the exchange rate (line *we*). The announced exchange rate was calculated by the author based on existing exchange rate regimes, while the critical reserve level ($r_c$) and the level of $\alpha$ were set at arbitrary levels and analyzed and compared for different values.

Interpreting the results should be done with bearing in mind the limitations of the data. First, published series on international reserves are an imperfect guide to the magnitude of foreign-exchange-market interventions. They are an expression of the gross foreign assets of the monetary authorities. Since operating procedures often arrange for stand-by credits in foreign currency, this is a potentially serious problem. When the central bank intervenes, it draws on it's credit lines without having to sell any of it's reported foreign assets.

Second, the monthly observations may not be of sufficient accuracy to identify every speculative attack. Speculative pressure against exchange rate regimes can mount quickly and be repelled through interest-rate increases or foreign-exchange-market intervention within a month. If an attack is initiated and ended within a couple of days, the average behavior of interest rates and international reserves over the month may not reveal the intensity of the short-lived speculative pressures.

## 5.2 Estimation procedures of the standard model for the Mexican peso-crisis

### 5.2.1 Variable determination and sample period selection

The Mexican exchange rate policy was altered eight times during the 1988-1995 period. Four of those changes consisted of strengthening of the controlled exchange rate regime (Feb.'88, Jan.'90, Dec.'90, and Nov.'91), because the government decreased or eliminated the rate of devaluation against the US dollar. Three of the adjustments can be interpreted as realignments (Jan.'89, Nov..'94, and dec.20-dec.21, 1994), since the (maximal) announced rate of devaluation was increased. The final policy switch, abandonment of the target zone with a ceiling band that was just increased by 15%, resulted in an exchange rate crisis, which is better known as the 1994 peso-crisis.

Both in periods of realignment and of crisis there should be speculative pressure in foreign exchange markets against the domestic currency. Therefore, one expects next-period collapse probabilities of controlled exchange rate regime to increase in such circumstances. If this speculative pressure is a reaction to the behavior of fundamental values in the economy, it should be possible to use a first-generation model to estimate those collapse probabilities in periods of turbulence on foreign exchange markets. The application of such a model on the Mexican exchange rate experience in the 1988-1995 period is useful, because different circumstances of the exchange rate regime (stability, realignment, and crisis) provide a good possibility to test the general explanatory power of a first generation model.

To estimate those collapse probabilities, it is required to make forecasts of the variables taken to be non-stochastic in the theoretical model, to estimate the stochastic process followed by domestic credit, shown by Eq.(6), and estimate the parameters of the money demand function. The risk premium is assumed to be constant for one period ahead and was determined as $r_t = i_t - i_t^* - (s_t - s_{t-1})$. In the first estimations $\alpha$ was set at 0, but also estimations were made with $\alpha$ between zero and one. Once all these data are put into the model, the conditional-on-collapse shadow exchange rate, Eq.(12), can be determined and used to estimate the one-period-ahead collapse probability, as expressed by Eq.(14).

Forecasts, made to generate $t+1$ values of the non-stochastic variables like the level of real income ($y_{t+1}$), were produced simply by using realized $t+1$ observations. As mentioned before, this way of modeling expectations is far from perfect, but is probably just as far of reality as any other simple way of expectations modeling and by far the simplest to use.

### 5.2.2 The money demand function

The estimation of the demand for real money balances was done with a standard approach, by regressing real money balances on the domestic interest rate and real income. Also it is needed to specify the lowest critical level of foreign exchange reserves that the monetary authorities will tolerate in period *t*+1. The standard model is estimated for a range of reserve floors between -$1 billion and +$1 billion of 1990 US dollars. The negative reserve floors capture the idea that a central bank may have had access to emergency lines of credit for the purpose of defending the exchange rate. Only if the results are qualitatively changed by altering the critical level of the reserve floor the outcomes of the model for $r_c \neq 0$ are presented in this paper.

To estimate the money demand parameters it must be taken into account that the demand for real money balances could well be unstable over the complete estimation interval. Potential parameter instability or structural breaks could occur at moments when the foreign exchange market regime of Mexico is changed, such as 1988:02, 1989:01, 1990:01, 1990:12, 1991:11, 1992:11 and 1994:12. However, the parameters of the money demand function are reasonable stable over the sample period and have the theoretically right sign. Further, the variables interest rate and real income are statistically significant, the explanatory power of the regression is large ($R^2$=0.96) and serial correlation seems to be a minor problem with a D-W statistic close to two. The regression results are presented in table 2.

*Table 2: Estimation results money demand function for period 1988-1995 Incl. observations: 82*

| Variable | Coefficient | t-Statistic | Adj. $R^2$ | D-W Stat. |
|---|---|---|---|---|
| *c* | 9.41 | 1.76 | 0.96 | 1.71 |
| *i* | – 0.59 | – 14.99 | | |
| *y* | 0.72 | 3.56 | | |
| *ma(1)* | 0.76 | 11.73 | | |

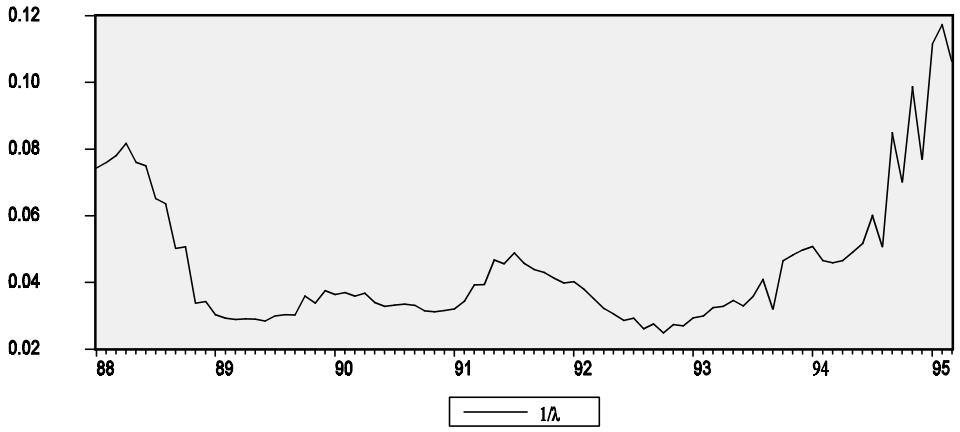
The estimates confirm the assumed relationship of rising interest rates that depress money demand and increasing income that leads to higher demand for real balances. Since estimation results of the demand for real money balanced were this good, the extension of adding an expected exchange rate change term to the regression equation was not carried out. However, in sample periods were the estimated parameters are very

unstable this might be a very useful exercise. Especially if the instability occurs in periods of an exchange rate policy switch or of high exchange rate volatility.

### 5.2.3 The process of domestic credit creation

To model the stochastic process of domestic credit expansion an ARIMA process was used. To model the forecast of domestic credit growth for period t+1 an ARIMA (1,1,1) process was applied to 18 month rolling samples and fit over all 18 month samples in the entire interval. The shocks to domestic credit are defined as the residuals from each of the rolling samples, i.e. $\epsilon_t = d_t - d_{t-1} - {}_{t-1}\mu_t$, and ${}_{t-1}\mu_t$, is defined as the forecast of the mean basic government deficit in period *t*-1. The latter was determined as ${}_{t-1}\mu_t = \Delta d_t - \epsilon_t$. The standard deviations of the domestic credit shocks ($1/\lambda$) can, following Goldberg (1994), be interpreted as the period *t* forecast of the potential scale of expected domestic credit shocks.

*Fig. 1: Expected volatility of domestic creation*




The volatility of domestic credit creation fluctuates between 0.02 and 0.12 throughout the sample period. The expected shocks of domestic credit growth sharply dropped after the fixed nominal exchange rate of the Mexican peso with the US dollar was put in place in the beginning of 1988. The latter decreased expected volatility by almost two thirds. After the introduction of the crawling peg, which consisted of a one peso a day devaluation of the peso against the US dollar in January 1989, expected volatility slowly started to rise. This rise continued, with some fluctuations and increasing in the end, until the middle of 1991. The adoption of an exchange rate band with a fixed floor and

a sliding, increasing ceiling in November 1991, led the expected volatility to drop gradually to its lowest level in the sample period. This point was reached in the fall 1992. The increase of the rate of devaluation of the band's ceiling from 20 cents to 40 cents a day in November 1992 marks the beginning of an almost exponentially rising expected volatility of domestic credit creation in Mexico. Just before the 1994 peso crisis the expected volatility reaches its highest point in the whole sample period. The latter could lead one to believe that some trouble was being expected with the exchange rate policy of the Mexican government at the end of 1994.

### 5.3 Extensions of the standard collapse model

To make an estimation of a collapse probability of a controlled exchange rate, using extensions first presented in Goldberg (1991a), it is necessary to make some additional preliminary estimates, forecasts and estimations of coefficients and their standard deviations. First, the application of an extended model requires estimation of additional stochastic variables in the model. The unexpected deviations from PPP ($\Omega_t$) need to be determined. Also the standard deviations, expressed by $1/\lambda_0$, have to be estimated. The latter are interpreted as indication of future relative price shocks. Further, forecasts of the systematic deviation from PPP, $\rho_{t+1}$, have to be made. The share of non-traded goods is arbitrary picked and its influence on results of the model is analyzed for different levels of the relative seize of the traded and the non-traded sectors in the economy. This means, $\alpha$ represents the share of goods which prices are not set in international markets and which are not faced with international competition.

The forecast of systematic deviations from PPP is estimated using an ARIMA (0,1,1) process on 18 months rolling samples. To do so, Eq. (16) is rewritten as $p_t - s_t - p^*_t = {}_{t-1}\rho_t + \Omega_t$ and ${}_{t-1}\rho_t$ is interpreted as the period $t$-1 forecast of $\rho_t$. The expected standard deviations of relative price shocks, $1/\lambda_0$, are determined by estimating the standard deviations of the forecast errors.

The extension to separate sources of domestic credit growth variability into shocks related to unexpected government revenues and uncertain availability of external credit flows was not applied in this paper. Goldberg (1994) showed that external credit supply shocks played a minor role in explaining exchange rate crises in Mexico between 1980 and 1988. More important is the fact that it is ambiguous anyway whether the realized international loans are a good measurement of the supply of external credit. A reduction in domestic credit supply could lead to an increase of the use of international credit domestically, while the total external credit supply need not have been altered at all. Alternatively, could a rise in the supply of external credit lead to a relative rise of the use of international credit, without any change in the supply of domestic credit. Even

more combinations are possible and, therefore, it is difficult to say something about external credit supply shocks in general.

## 5.4 Estimation results

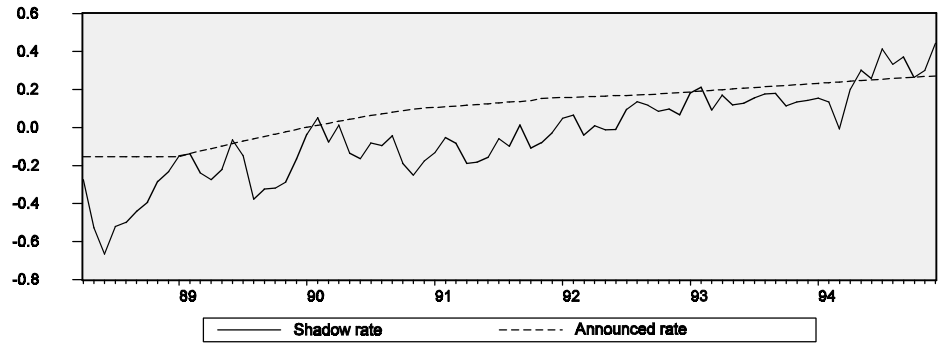
### 5.4.1 The standard model results

The predicted collapse probabilities and the shadow exchange rate are generated using the parameter estimates from the money demand function described above. Both are generated for the 1988-1995 period. Goldberg (1994) interprets the estimated shadow exchange rate as "providing a lower bound for an exchange rate consistent with the contemporaneous state of monetary and fiscal conditions in the economy" (Goldberg (1994), pg.425). Therefore, as long as the shadow exchange rate remains above the fixed or pegged exchange rate or the ceiling of the exchange rate band, the fundamental conditions in the economy are good enough to maintain the current exchange rate regime.

In Figure 2 the shadow exchange rate and the official exchange rate are plotted. It shows that, except for a few very short periods, the exchange rate was above its lower bound until the beginning of 1994. In the spring of 1994, around the time of the Colosio assassination, the official rate went below its lower bound and collapse probabilities started to rise (see Figure 3).

It should be noted that Mexico adopted an exchange rate band in November 1991. This band consisted of a fixed floor, set at 3050 old pesos per dollar, and a sliding ceiling of 20 cents per day. This rate of devaluation of the band's ceiling was accelerated to 40 old cents per day (0.0004 new pesos) in November 1992. In the estimation procedures the announced exchange rate between November 1991 and December 1994 was modeled as being the upper ceiling of the exchange rate band. The collapse probabilities, therefore, indicate the risk that the exchange rate band will not survive, but neglects the possibility this happens as result of an appreciation of the Mexican peso against the US dollar. The latter, however, did not seem very plausible and the collapse probabilities are probably not distorted to much by this simplifying assumption. The rest of the announced exchange rate was constructed by using the preannounced rate of devaluation as described in Table 1.

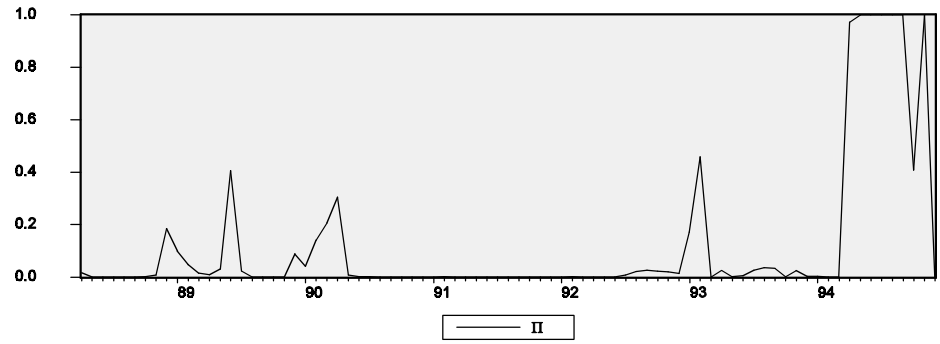
*Fig. 2: The announced and shadow exchange rate for the 1988-1995 period*




The difference in the (log) shadow floating exchange rate and the (log) announced exchange rate are shown in figure 2. During the last months of 1988 exchange rate pressure against the peso increased as is expressed by a rising shadow exchange rate in figure 2. In January 1989 the shadow exchange rate reached the same level as the announced rate. At that time a policy switch was made by the government and the fixed exchange rate regime was replaced by a crawling peg. Through 1989 and the beginning of 1990 some exchange rate pressure remained, but the shadow rate just peak's for very short periods above the announced rate. In the period between 1990 and the end of 1992 the official exchange rate was well above its lower bound and the rate of crawl was brought back from 80 old cents per day to a sliding band ceiling of 20 old cents per day. During 1992 exchange rate pressure started accumulating again and in the beginning of 1993, just after the acceleration of the band's slide to 40 old cents per day, the shadow exchange rate was higher that the announced exchange rate for a short period. After that it took until the beginning of 1994, as stated above, before strong speculative pressure pushed the shadow exchange rate above the announced rate for a substantial period. The temporary fall back of foreign exchange pressure in September and October could not prevent the final collapse that occurred in December after the speculative pressure had pushed up the shadow exchange rate once more.

Predicted collapse probabilities indicate that speculative motives increase demand for US dollars in the foreign exchange markets, because large capital gains can be captured as a large devaluation of the Mexican peso takes place. In periods of high collapse probabilities one would expect heavy speculation against the peso. In figure 3 the one-period-ahead collapse probabilities of the Mexican peso produced by the model are shown. They seem to indicate that an exchange rate crisis was inevitable in 1994, since the model predicts a probability of collapse of one for almost three quarters of the year.

*Fig. 3: Collapse probabilities of the Mexican peso between 1988-1995*



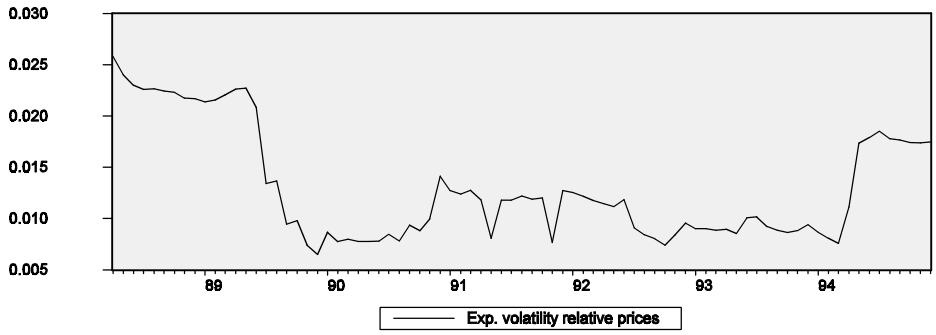

As mentioned before there is some turbulence in the foreign exchange market before 1994, at times of minor adjustments that were made to the exchange regime, but the model indicates that only in 1994 the exchange rate collapse should really have been expected.

### 5.4.2 The extended model results

As described above an extended version of the collapse model was also estimated. In this model the assumption of strict purchasing power parity does no longer hold. It is now assumed that the price level of domestic non-traded goods is determined partially by domestic conditions, while the domestically consumed traded goods are priced according to the law of one price. The weight of the non-traded goods in domestic expenditures, $\alpha$, is assumed exogenously given and was analyzed for values between 0.1 and 0.5. Unless the estimation results were qualitatively changed by altering its value $\alpha$ was set at 0.25. The systematic deviation from purchasing power parity of the price index of the non-traded goods, $\rho_t$, and the expected standard deviations of relative price shocks, $1/\lambda_0$, were estimated as described in section 5.3.

With the adoption of a fixed exchange rate regime against the US dollar in the beginning 1988 the risk of relative price shocks was sharply reduced. Therefore, the expected volatility of relative prices dropped gradually throughout 1988 and sharply after the implementation of the crawling peg of a preannounced rate of devaluation from 1 old peso per day. The latter exchange rate regime was probably believed to be much more realistic and, therefore, credible than a completely fixed exchange rate regime. This is not surprising taken the exchange rate history of Mexico into account.

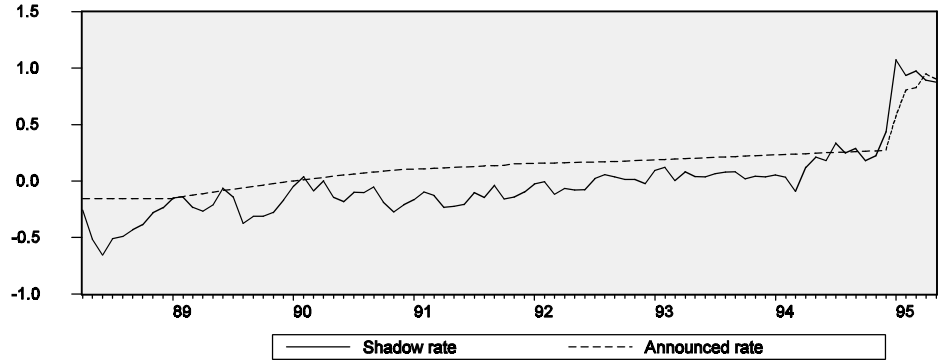
*Fig. 5: The expected standard deviations of relative price shocks in Mexico*




As becomes clear from figure 5, the exchange rate policy of the Mexican government helped bringing down expected volatility of relative prices in the 1990's. After a strong decrease in 1989, expected volatility started slowly rising again in 1990. In the period between January 1990 and November 1992 the exchange rate regime was adjusted four times, which resulted in a slightly rising and fluctuating expected volatility of relative prices. However, it never even reached half of the 1988 levels. The implementation of the exchange rate band, with a sliding ceiling of 0.0004 new pesos per day, stabilized volatility at a low level between end 1992 and the beginning of 1994. After the Colosio assassination of April 1994 uncertainty in the Mexican economy rose and the expected volatility of relative prices increased to the highest level in almost five years.

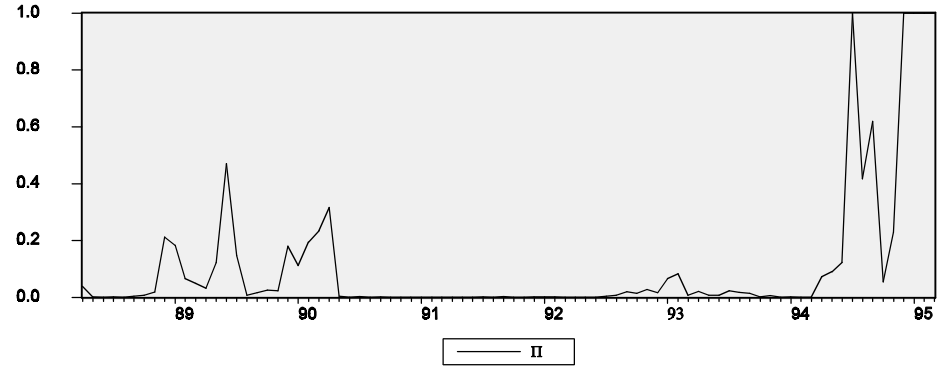
The influence of the changes in relative prices on the shadow exchange rate and the collapse probabilities are expressed in the figures 6, 7, and 8. The shadow exchange rate is not really changed much. It just seems to shift a little downwards and lays a bit more under the announced exchange rate than in figure 2.

*Fig. 6: The shadow and announced exchange rate with systematic deviations from PPP*



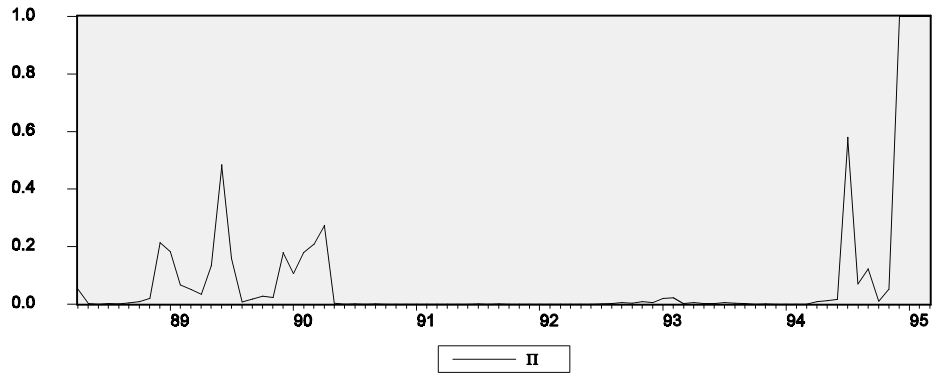

The influence of the alternative relative price relationship on the collapse probabilities is a little more difficult to understand. There it does matter what is assumed about the share of domestic expenditure that is spent on non-tradeable goods. The latter is determined by the value that is picked for $\alpha$. The most noticeable effects, compared to the collapse probabilities as expressed in figure 3, are the elimination of crash probabilities around the beginning of 1993 and the reduction of probabilities of a crisis in third quarter of 1994. After a peak in the election month August the collapse chances dropped sharply and only rise strongly just before the December 1994 crash.

*Fig. 7: Collapse probabilities with systematic deviation from PPP and $\alpha$ set at 0.25*



It is interesting to see what happens if the share of domestic expenditure on non-traded goods is assumed to be 45% or larger. Below that level the structure of the collapse probabilities figure does not qualitatively change. With an $\alpha$ of 0.45 or bigger the chances of a crash in the first eight month's of 1994 become smaller and smaller, the larger $\alpha$ is set. To show this result figure 8 presents the collapse probabilities for a value of $\alpha$ of 0.45. The collapse probability of an exchange rate crash in the end of 1994 is unaltered by manipulating the level of $\alpha$. The latter shows that the model results are pretty robust and firmly predict a currency crisis in the end of 1994.

*Fig. 8: Collapse probabilities with systematic deviation from PPP and $\alpha$ set at 0.45*




## 5.5 Résumé of the Mexico estimations

In this paper on studying exchange rate crises, a simple collapse model, based on the standard Flood and Garber-model, was used to estimate collapse probabilities of the Mexican peso in the period between 1988-1995. In that period Mexico experienced several periods of speculative pressure on the peso and the model predicts collapse probabilities larger than zero for most of those periods. In 1994 the model is over-estimating the collapse probabilities a bit, as the first collapse was expected to occur in May, just after the Colosio assassination. The predictions might not be perfect, but they give at least a good indication about the foreign exchange pressure that is developing in the international capital markets. After the presidential elections in August the collapse probabilities drop below one for two month's, but rise to one again just before the exchange rate collapse in December 1994. Therefore, the probabilities might be a little too large, but taken over the whole sample period, they do indicate that the chances

of an exchange rate crisis were by far the biggest in the month's leading up to the 1994 peso crisis. According to the model an exchange rate crisis was certain, it just took a little time to arrive.

Goldberg (1994) did a similar estimation for the preceding period of 1980 until 1986. Although Goldberg (1994) used a more extensive model, the results obtained by this model are very similar to the Goldberg (1994) results, if this model is applied to the 1980-1986 period. The behavior of the variance of domestic credit, the shadow exchange rate and the collapse probabilities are basically the same throughout the sample period. Therefore, the model used in this paper should be able to serve as a useful tool to find out more about the general explanatory power of first-generation collapse models.

The latter should not be a reason to forget the simplifying assumptions made in this model and the possibilities to improve the model. The results of the model do, however, give an indication of the usefulness of those possible extensions. It is useful to know what additional information can be abstracted from an extended version of the model. To do this one has to know the simple model results as well as the extended model outcomes. Based on the results of this model, the Goldberg (1994) extension of the model seems to provide limited additional information about exchange rate crises and predictions of collapse probabilities.

The most important factor in the model is the domestic credit variable. The simplifying assumptions about the (constant) demand for real money balances and expectations of agents cause the shadow exchange rate to be mainly driven by domestic credit growth. Altering the critical reserve floor or the share of non-traded goods in domestic expenditure sometimes influences the outcomes of the model, but in general does not change the qualitative results when this model is used. However, more sophisticated modeling of relative prices is a useful extension of the model. When the assumption of strict PPP is dropped the collapse probabilities become more realistic, without creating doubts about the robustness of the model. A good combination of more sophisticated modeling of demand for money balances, the share of domestic goods in expenditure and deviation from strict PPP could further improve the results of this first generation model.

However, as long as the expectations modeling remains unaltered the gap between first and second generation models will remain to exist. The first generations models, with or without extensions and improvements in other parts of the model, remain to be driven by fundamental values as long as the expectations modeling is not really changed. A fusion between the different generations of models might be achieved if real market expectations are correctly introduced into the model. New techniques to abstract those expectations from option prices could be a possibility to achieve this goal (Soderlind and Svensson, 1997 and Campa et al., 1997). This kind of expectations modeling make the model react to irrational panics of international investors and self-

fulfilling speculative attacks on a currency. A third generation model will then be born, which combines the qualities of both models, and reacts to both fundamental values and psychological influences. This will be a major improvement in the general explanatory power of collapse models and, therefore, is a big challenge for future research.

An other useful application of these new expectations modeling techniques is to make a separate estimation of the expected size and the expected probability of an exchange rate adjustment (Bekeart, 1996). The collapse probabilities that are produced by the model in this paper are all results from a multiplication of the size of the exchange rate change times the probability of its occurrence. High collapse probabilities can be caused by large expected exchange rate changes together with a small probability of occurrence or by a relatively small expected exchange rate adjustment accompanied by a high probability of occurrence. If both the exchange rate change and the probability of occurrence are expected to be high, than the collapse probabilities will obviously be high as well.

Just like in most other empirical applications of a first generation collapse model in the past, the results of the Mexico estimations are promising and the model does seem to predict the exchange rate crisis pretty well. However, in all those studies the model was only tested on one country and often over a very limited period of time. To be really able to say at least something about the general explanatory power of these kind of models, they should not only be tested over longer periods of time, but also be applied to different crises in different countries. For that reason the model was tested on the exchange rate crises that occurred in Europe in 1992, where some countries were forced to leave the ERM and others had a lot of problems remaining part of that exchange rate system. To prevent the whole European Exchange Rate Mechanism to fall apart the bandwidths for most participating countries were widened in the end of 1992. The interesting thing of testing the model on those crises is that it's widely believed these European crises were much more driven by irrational or purely speculative motives and less the result of problematic fundamentals.

## 5.6 Additional application of the model: the 1992 ERM-crisis

### 5.6.1 Estimation procedures

As mentioned above it is widely believed that the crises that occurred in the Europe's Exchange Rate Mechanism (ERM) in 1992 were mainly caused by speculative motives, and were not based on fundamental economic values. These crises, therefore, provide a test to look at the general explanatory power of the standard collapse models. One would expect those models not to work very well in these circumstances. If the model does give nice results one should keep in mind this probably should be interpreted as

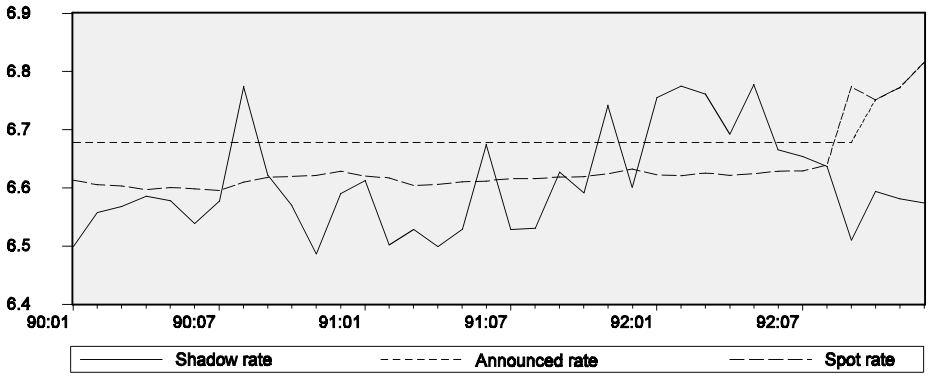
proof that fundamental values played a larger role that some people believe in the 1992 ERM-crises. It does not mean that these kind of models are capable of identifying irrational or self-fulfilling panics of investors.

To apply the model to the ERM-crises the exchange rate of several European currencies against the German D-mark was analyzed. Similar to the approach used for the last two years of the Mexico estimations, the upper band of the exchange rate target zone was modeled to be the announced exchange rate. The latter implies that the collapse probabilities indicate whether or not the target zone is viable and that it is assumed that the analyzed European currencies would not strongly appreciate against the D-mark. Both simple and extended versions of the model were estimated for the ERM-crises, but only if the estimation results differ qualitatively the extended model outcomes are presented. In the figures the natural logarithm's of spot, shadow and announced exchange rates are shown. The data were all drawn from the CD-rom version of the International Financial Statistics (IFS) of the IMF and the same data-series were used as during the Mexico estimations.

### 5.6.2 Italy

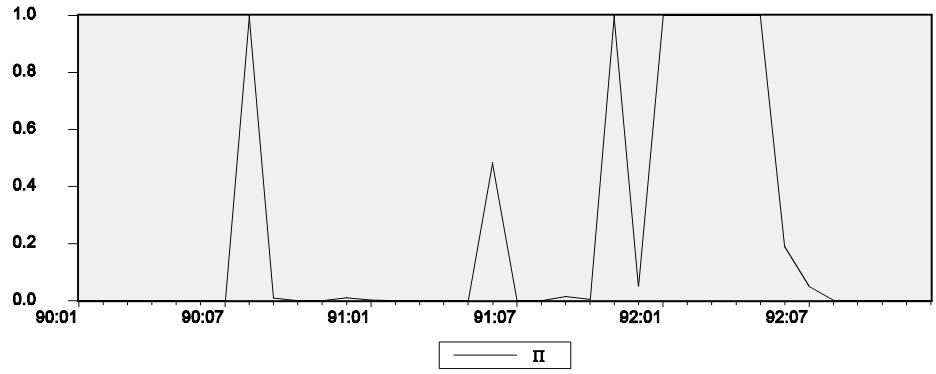
One of the most interesting European currencies to analyze, when looking at exchange rate crises, is the Italian lira. Italy has a history of high inflation rates for European standards and had several problems to remain part of the ERM. After the 1992 crisis Italy was forced to leave the ERM for a while, but the lira re-entered in November 1996 and Italy now even hopes to join the '*strong currency*' countries in Europe in participating in the Euro in the beginning of 1999.

*Fig. 9: The Italian exchange rates for the 1990-1993 period*



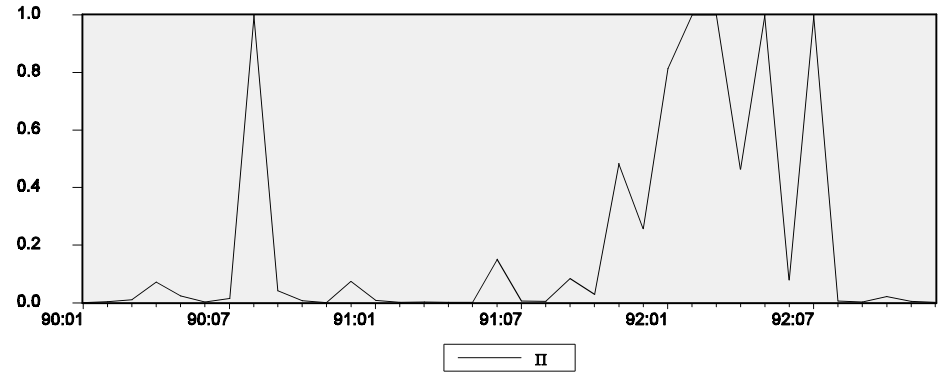
The estimated shadow exchange rate and the collapse probabilities of the lira, for the first period Italy was part of the ERM, are shown in figures 9 and 10. The shadow exchange rate is much more volatile than the spot rate for the entire period and behaves a little strange around the time of the 1992 crisis. The shadow rate drops sharply in the last three month's before the crash in September 1992 and than starts rising again from September onwards. The latter produces positive one-period-ahead collapse probabilities from the beginning of 1992 until August 1992. Once again, the model probably over-estimates the collapse chances, but seems to predict the crisis period fairly well. However, in the Italy estimations there are three other periods (Aug.'90, Jun.'91 and Nov.'91) where the model suggests that crises should have occurred, while at that time the spot exchange rate had no problem remaining within the bands of the target zone.

*Figure 10: Collapse probabilities for the Italian lira between 1990 and 1993.*




The doubts about the validity of the Italian estimation results are further increased when the estimation results of the real money demand function are analyzed. The demand for real money balances is assumed to be stable and is estimated for the period between 1989 and 1994. To correct the estimations for serial correlation the variables real money balances, domestic interest rate and real income where used as instrumental variables. The latter results in a Durbin-Watson statistic of 1.77. However, both the interest rate and the real income variables are statistically significant (absolute value of the t-statistic above 3), but have the theoretically wrong sign. The coefficient for the interest rate is 0.53, while the real income parameter is estimated to be -4.04.

*Figure 11: Extended model collapse probabilities of the lira in the 1990-1993 period.*

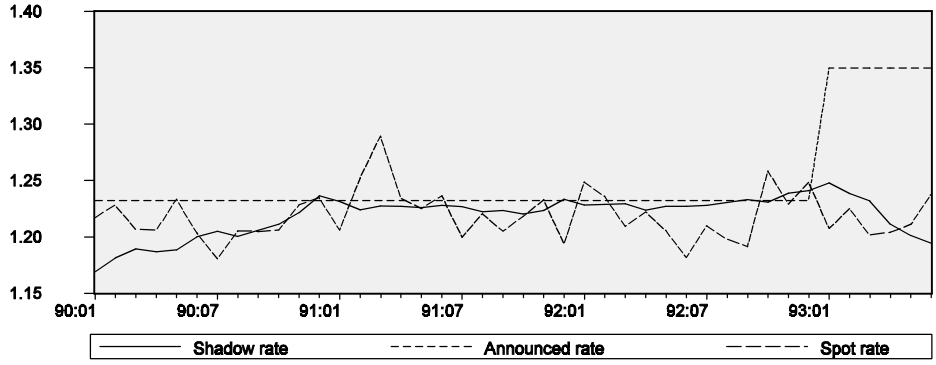



When the extended model is estimated for Italy the results do not change very much. The big collapse probabilities in June ‘91 and November ‘91 are reduced substantially, but do not disappear. During 1992 the collapse probabilities behave a little different as well, but still start rising in the beginning of ‘92 and keep on being high until August ‘92, as shown in figure 11.

### 5.6.3 France

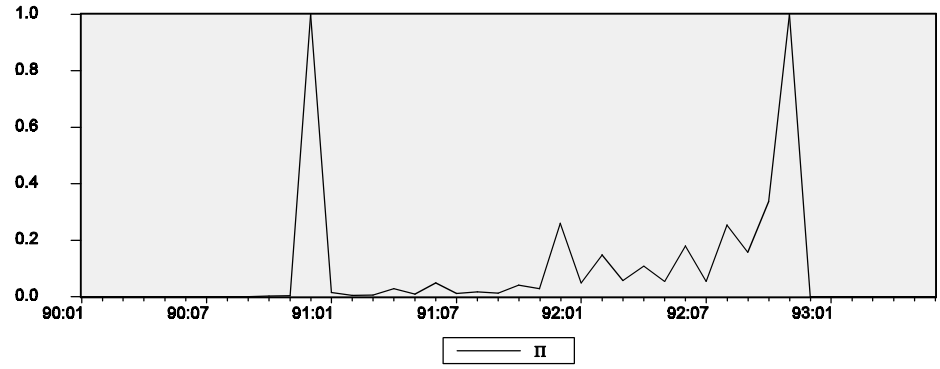
In the same period the Italian lira had to leave the ERM, the French franc suffered from heavy speculative pressure and was almost forced to leave the ERM as well. Widening of the bands to 15% in the end of 1992 was enough, however, to prevent the French currency to drop out of the ERM. As shown in figure 12 the French shadow exchange rate is, in contrast to the Italian situation, less volatile than the spot rate in the 1990-1993 period. This could interpreted as a result of more stable fundamental values in France and exchange rate problems that are largely caused by speculative and irrational behavior of international investors.

*Figure 12: The French exchange rates for the 1990-1993 period.*




Except for a very short period in the December 1990, the shadow rate remains below the upper band of the target zone until the second half of 1992. Although the franc remained in the ERM, the prediction of a crisis in the end of 1990 is not such a bad prediction, since the spot rate rose above the upper band for small period of time in the beginning of 1991. In the end of 1991 the model starts predicting collapse probabilities larger than 0.1 again.

*Figure 13: The collapse probabilities for the French franc between 1990-1993.*




Throughout 1992 chances of a crisis remain positive and according to the model the exchange rate bands were widened just in time, because the collapse probability rose to one in November and the band was widened in December. However, in reality the

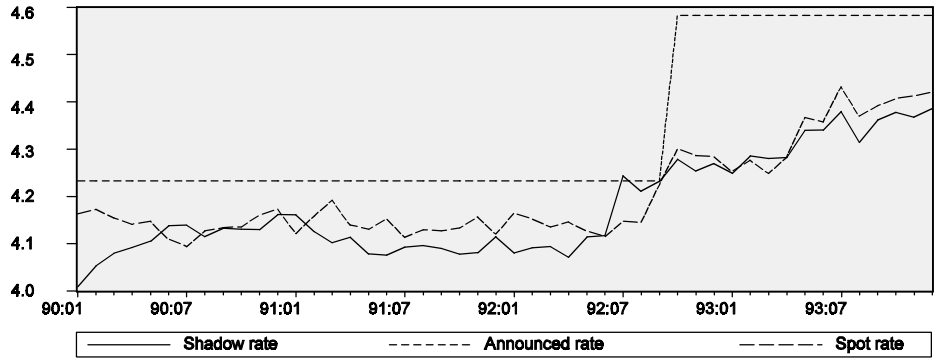
biggest collapse chances were probably in September 1992 and are not very accurate predicted by the model. Figure 13 presents the collapse probabilities for France.

The estimation of the demand for real money balances for France was done over the 1990-1996 interval and produces much more reliable results than the Italian estimation. The interest rate coefficient is negative and statistically significant, the real income variable has a positive sign, but is statistically insignificant, the adjusted R-squared is 0.44 and the Durbin-Watson statistic is 1.66. Therefore, it seems reasonable to assume that the limited explanatory power of the model in this case is not caused by strange behavior of fundamentals, but by influences on the exchange rate that are not captured by this model, such as an contagious irrational panic among investors. The estimation results of the extended model do not change anything if compared with the simple model and, therefore, are not further presented here.

### 5.6.4 Spain

In September 1992 the Spanish peseta was almost forced to leave the ERM, but could be kept inside the target zone as the latter was widened just in time. The Spanish exchange rate is pretty well described by the simple model, as is shown in figure 14. The shadow exchange rate moves along the spot rate quite closely and the volatility of the shadow and spot exchange rate are almost equal as well. This seems to indicate that the same fundamental values are influencing these two exchange rates. This argument is further supported by the predictive power of the model in the Spanish case. The collapse probabilities remain zero throughout the whole 1990-1994 period, except for July and August of 1992. In the two month's leading up to the '*crisis*' month September, the collapse probabilities peaked to 0.7 and the shadow rate came above the upper band of the target zone for a short while. The Spanish crisis probably had more fundamental reasons than most of the other crises that occurred in Europe in this same period.

*Figure 14: The Spanish exchange rates for the 1990-1994 period*



An important note that has to be made with the Spanish estimation results is the fact that the demand for real money balances is significantly unstable for the 1990-1995 period. There is a structural break in the money demand parameters around June 1992. Therefore, the money demand function was estimated separately for the periods of 1990:01-1992:06 and 1992:07-1994:12. The results are presented in Table 3.

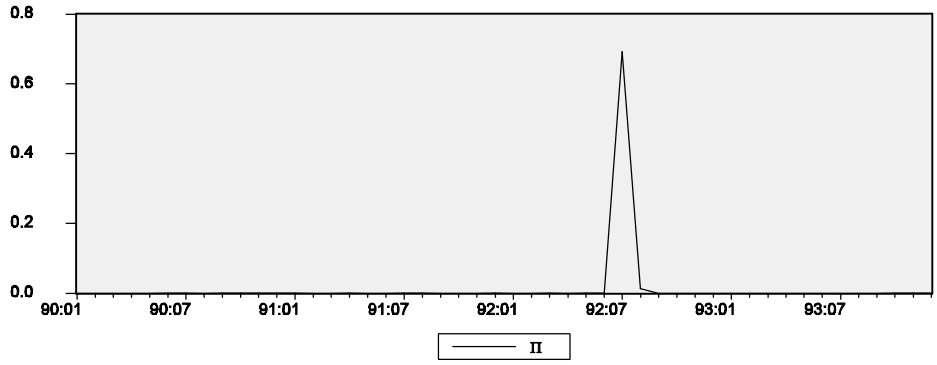
*Table 3: Spanish estimation results real money demand function for period 1990-1994*

| Variable | Coefficient | t-Statistic | Adj. $R^2$ | D-W Stat. |
|---|---|---|---|---|
| $c_1$ | 27.98 | 261.77 | 0.76 | 1.74 |
| $c_2$ | 27.15 | 581.04 | 0.78 | 1.9 |
| $i_1$ | – 0.42 | – 4.26 | | |
| $i_2$ | 0.36 | 5.95 | | |
| $y_1$ | 0.44 | 1.75 | | |
| $y_2$ | 0.89 | 3.47 | | |
| $ma(1)_1$ | 0.95 | 51.9 | | |
| $ma(1)_2$ | 0.57 | 3.57 | | |

The variables of the estimation made for the 1990:01-1992:06 period have subscript one and the variable for the second period have subscript two. The most contrasting difference between the two sub-periods is the estimated interest rate coefficient. In the first interval, the interest rate parameter is negative and significant, while in the second interval it is also statistically significant, but positive. Further it is noticeable that the real income elasticity of the real money demand is doubled in the second period and becomes much more significant as well. Using these different parameters for the two different intervals produces the collapse probabilities that are shown in figure 15.

Once again it should be remembered that the predictive power of the simple model is probably proof of the fact that the Spanish exchange rate was strongly influenced by fundamental economic values. The results should not be interpreted as being proof that this model can predict crises caused by speculative or irrational behavior. Since the extended model results do not alter the results obtained with the simple model, the extended model results are not shown here.

*Figure 15: The Spanish collapse probabilities for 1990-1994 period*




### 5.6.5 England

The British pound was forced to leave the ERM in August 1992, but it is very doubtful wether a first generation model could help explaining the causes of this crash. The shadow rate is below the upper band of the target zone for the entire period the British pound was part of the ERM and the collapse probabilities are very close to zero the entire period as well.

*Fig. 16: Collapse probabilities British pound*

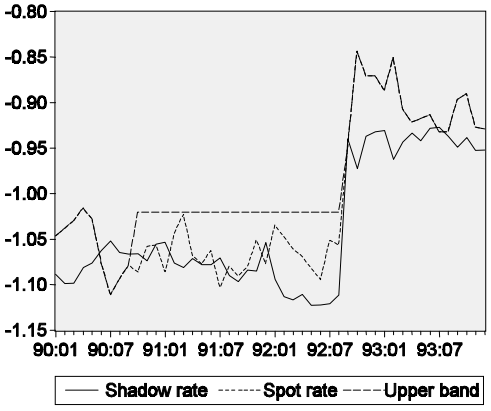
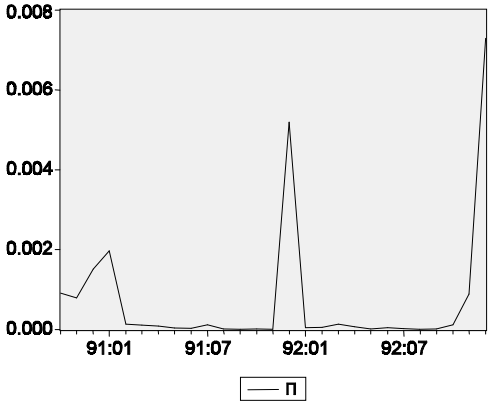



*Fig. 17: Exchange rates British pound*




Once again the spot exchange rate is more volatile than the shadow exchange rate. As mentioned before this might be a sign that the spot exchange rate is driven, at least partly, by variables not included in this model. The sharp rise of the shadow exchange

rate in late 1992 is probably not the cause, but the result of the collapsing British pound. The structural break in the demand for real money balances, that occurred in August '92, and estimation of the money demand function over sub-intervals produce a shadow exchange rate that peaks, just like the spot rate, one month after the actual crash occurred. Therefore, although the shadow rate makes a discrete jump in the end of 1992, the collapse probabilities remain very close to zero over the entire interval.

The results of the estimated British money demand functions are shown in Table 4. Coefficients with subscript one are from the estimation that was done over the 1990:01-1992:08 period, while the second period was from 1992:09 until 1994:06. The fact that currency substitution motives of agents might have caused the structural break, could also help explain the couple strange parameters that are estimated in both periods. In the first sub interval the real income coefficient has a negative sign, but is statistically insignificant as well. In the second period the real income parameter is positive and significant, but now the interest rate parameter becomes insignificant. These problems might be reduced if an exchange rate expectations variable is used in the estimation of the demand for real money balances.

*Table 4: Estimation results British demand for real money balances 1990-1994*

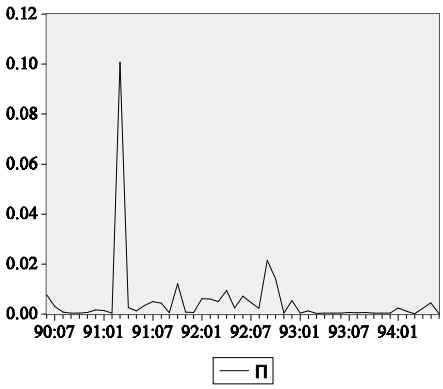
| Variable | Coefficient | t-Statistic | Adj. $R^2$ | D-W Stat. |
|---|---|---|---|---|
| $c_1$ | 28.43 | 388.06 | 0.69 | 1.58 |
| $c_2$ | 28.23 | 591.17 | 0.6 | 2.02 |
| $i_1$ | – 0.16 | – 2.36 | | |
| $i_2$ | 0.08 | – 0.77 | | |
| $y_1$ | – 0.16 | – 0.33 | | |
| $y_2$ | 1.34 | 3.36 | | |
| $ma(1)_1$ | 0.77 | 5.58 | | |
| $ma(1)_2$ | 0.2 | 0.86 | | |

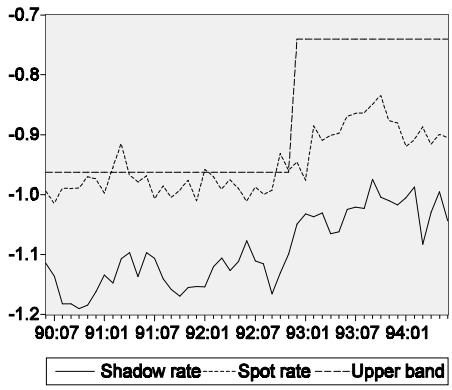
### 5.6.6 Belgium, Ireland and Denmark

An other example of the limited power of the model is given when the model is applied to the Belgium franc, that was under strong speculative pressure as well in September 1992. The Belgium franc was not forced to leave the ERM, but had to widen its bandwidth to 15%. The collapse probabilities that the model predicts occur too late and are probably the result of the structural break in the estimated money demand function

(break at 1992:11). The shadow exchange rate is below the spot rate for most of the interval, which seems to indicate the Belgium franc had no structural problems remaining part of the ERM. However, it is hard to say much more, based on the model outcomes, about the causes of the foreign exchange market pressure against the Belgium franc in September 1992. In spite of the latter, the estimation results are presented in figures 18 and 19.

*Fig. 18: Collapse probabilities Belgium franc* *Fig. 19: Exchange rates Belgium franc*




The results for the Irish pound, that had to be supported with heavy intervention in the foreign exchange market in November 1992, do also not increase the general explanatory power of the standard collapse model. The shadow exchange rate is well below the spot exchange rate for the entire 1990-1994 period and the collapse probabilities are very small over the entire interval as well. The results are presented is figures 20 and 21.

*Fig. 20: Collapse probabilities Irish pound*

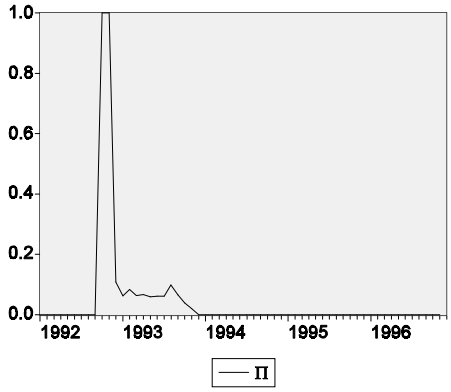
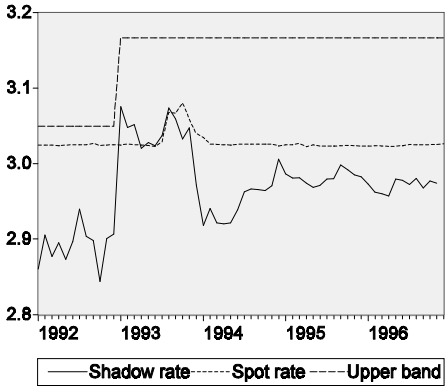



*Fig. 21: Exchange rates Irish pound*




Application of the model to Danish krona produces similar result as the Irish case. The shadow exchange rate is below the spot rate for almost the entire interval and the collapse probabilities are very small. The foreign exchange market pressure that accumulated in September 1992 is not well predicted by the model and the shadow exchange rate is more volatile than the spot rate. These unconvincing results are shown in figures 22 and 23.

*Fig. 22: Collapse probabilities Danish krona*

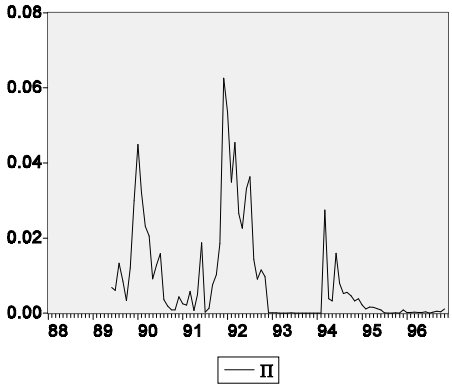



*Fig. 23: Exchange rates Danish krona*


Some of the problems the standard collapse model has in explaining speculative attacks might be solved by making better and more extensive estimations of the demand for real money balances. The estimated parameters of the money demand function play an

important role in the model and changes in those coefficients can have strong influences on the outcomes of the model. As already mentioned before, it could be very helpful to include a proxy for the expected exchange rate development in the money demand estimation to capture the effect that the currency substitution motive of agents can have on money demand. The estimation results of the Belgium, Irish and Danish money demand functions are presented in table 5 and the sometimes strange outcomes indicate that a lot of improvement can be made on this subject.

*Table 5: Estimated money demand functions for Belgium, Ireland and Danmark.*

| | $c_1$ | t-value | $c_2$ | t-value | $c_3$ | t-value | Adj. $R^2$ | D-W Stat. |
|---|---|---|---|---|---|---|---|---|
| *Belgium 1990:12-1992:11* | 27.42 | 48.8 | – 1.35 | – 1.87 | – 1.20 | – 1.65 | 0.65 | 0.89 |
| *Belgium 1992:12-1996:12* | 27.18 | 4045.4 | – 0.23 | – 16.30 | 0.02 | 0.44 | 0.92 | 1.71 |
| *Ireland 1990:06-1994:06* | 24.35 | 1511.3 | -0.008 | -0.97 | 0.5 | 5.85 | 0.67 | 2.06 |
| *Danmark 1988:01-1996:12* | 25.6 | 519.77 | 0.04 | 0.67 | 0.29 | 2.47 | 0.36 | 1.77 |

The estimated constant is expressed by $c_1$, while the coefficients of the domestic interest rate and real income are respectively $c_2$ and $c_3$. The regressions were also made with the real money balances, the interest rate and real income as instrumental variables, but in none of the cases the regression outcomes improved. The results clearly show the opportunities for making improvements in estimating money demand functions for those countries. In the first period the Belgium money demand is estimated for the coefficients of the interest rate and income are statistically insignificant and the Durbin-Watson statistic is even below one. In the second interval the interest rate parameter becomes significant and the Durbin-Watson statistic rises to 1.71, but the income coefficient remains insignificant.

The Irish results are the best of the three countries. There is no structural break in the parameter values over a period of four years. The interest rate coefficient has a negative sign, the income coefficient a positive sign and the Durbin-Watson statistic is very close to two. The only problem is the insignificance of the interest rate parameter. The Danish money demand function is estimated over the longest period (nine years), but does have not very impressive results. The interest rate coefficient is positive and insignificant and

the adjusted R-squared is only 0.36. However, the real income coefficient is positive and significant and the Durbin-Watson statistic is reasonable as well with 1.77.

### 5.6.7 Résumé ERM estimations

The predictive power of the standard first generation models is seriously tested when applied to European currencies that participated in the ERM. The estimation results confirm the assumed limited explanatory power of first generation collapse models. The speculative pressure against the Spanish peseta is predicted pretty well by the model, but that is the only one of the seven currencies crises that the model is applied to. In the case of the Italian lira and the French franc the (potential) crises were predicted as well, although the exact timing of the collapse was not perfectly pinned down by the model outcomes. Some collapse probabilities were predicted in periods of relative tranquillity and sometimes several month's of high collapse probabilities preceded the actual collapse, thereby reducing the accuracy of the model predictions.

For the other four currencies the model was tested on, the results showed clearly that first generation models do not provide a complete and solid structure to analyze all the exchange rate crises that occurred in the past and that will occur in the future. The collapse probabilities remain close to zero in crisis periods and the shadow exchange rate differs a lot from the spot exchange rate in most cases. Some of these problems might be reduced when the money demand functions are estimated with more variables (including the currency substitution motive for example) or with other more refined methods. However, this will not solve the whole problem. To capture the influence of speculative, contagious and irrational behavior of international investors a good empirically testable second generation model is needed. This could also be a (third generation) model that combines the influences market expectations and economic fundamentals have on the nominal exchange rate and on each other. These kind of models have not been produced yet.

However, the fact that first generation models are not perfect does not mean that they are useless at all. If fundamentals are the main cause of an exchange rate crisis these models do predict the collapse pretty well and if they are refined even more it might be possible to prevent these models from ever predicting a crisis that will not occur at all. A model that does not predict everything, but if it does, is always right, is of a lot of interest. Such a model would be used very much, because at least some of the sources of exchange rate risk could be reduced by using it. This is the goal that should be set for first generation collapse models, while other efforts should be made at the same time to produce empirically testable second generation model and to combine the features of the two models into a complete model.

## 6. Concluding remarks

As becomes very clear after analyzing the literature and estimation results of this research, the classical speculative attack model does not provide all the answers to questions about the causes of exchange rate crises. In some cases the model seems to have explanatory power (Mexico), but in other situations (ERM-crises) the model is incapable to produce reliable one-period-ahead collapse probabilities. In recent literature it is often argued that second-generation collapse models are needed to describe this kind of crises, which are assumed to result from self-fulfilling panics of international investors. It is sometimes stated that exchange rate crises with fundamental causes can be explained with first-generation collapse models and that crises resulting purely from speculative behavior of investors should be understood using second-generation models. One should have some doubt, however, wether the combination of first- and second-generation collapse models will capture the whole picture. There seem to be a lot of other improvements possible to first-generation models that can also increase the general explanatory power of the collapse models.

To see this let's shortly discuss the benefits and limitations of the classical speculative attack models. One of the most important positive points of the first-generation models is that they sometimes work quite well. If a collapse is the result of an excessive domestic credit growth or volatility, the model will predict collapse probabilities fairly well. In both theoretical and empirical literature domestic credit is believed to be one of the most important factors that can cause exchange rate crises. Therefore, a substantial part of all the crises occurring in the world probably is reasonably well explained using a first-generation model. With some of the extensions like allowing for deviations from PPP, modeling the influence from external credit supply, more sophisticated estimation of the money demand and including a proxy for the structure of a country's debt the model intuitively improves and should increase in general explanatory power. The latter, however, is only partially supported by empirical results.

A good example of a useful extension made in the past is the introduction of uncertainty about the rate of domestic credit growth. This was first done by Flood and Garber (1984a) and also included in the model used in this paper. The unanticipated increases in domestic credit now can cause the shadow exchange rate to exceed the announced rate temporarily. However, the larger the variance of the process governing the domestic credit creation, the greater the probability of a regime shift and, therefore, the greater the probability of a speculative attack. So, the influence of a possible policy switch is included in the model, but better estimations about agents expectations concerning a possible policy switch are needed for sure.

The latter is just one of the limitations of the model that are the result of the basic assumptions of the model. This is not surprising, since every model is limited by its own assumptions. The assumption of perfect capital mobility, however, might not be perfect for all countries in the world, but in general is probably true. The other assumptions of perfect foresight and a constant real money demand are a lot less obvious.

First of all, the modeling of expectations in empirical models is one of the most difficult things to do well for economic researchers. To assume that agents have perfect foresight is of course far from perfect and should be improved most definitely. Introduction of uncertainty alone is not enough to feel comfortable with assumptions about expectations in the model. The simple theoretical assumptions of adaptive, rational or perfect foresight expectations are not convincing or do not produce impressive results when empirically tested. New techniques to abstract investors expectations from interest and forward rates and from asset and option prices should be exploited with much more effort and could provide a large enrichment for the speculative attack models. Using market prices to construct agents expectations might even make it possible to combine first- and second generation model into one unified collapse model. The latter because a self-fulfilling panic should have an instant effect on market prices. In appendix A2 some alternative techniques to abstract future expectations from market prices are presented.

Secondly, the demand for real money balances could very well not be constant through time in a certain country. Especially in countries, like Mexico, with a long history of exchange rate crises the currency substitution motive will be of great influence on the demand for real money balances. Once again to make nice money demand estimations a reliable estimate of market expectations about the future exchange rate is needed, which might be possible with the techniques mentioned above.

Thirdly, the model can be extended by assuming systematic deviations from purchasing power parity and decomposing the disturbances to domestic credit creation into domestic and foreign sources. The latter are the Goldberg (1994) extensions, which provide more detailed information on the influence of domestic monetary shocks, external credit supply shocks and relative price shocks on exchange rate crises.

Fourthly, variables like $s_{t+1}^{a}$ and $r_c$ are determined relatively simple in this paper and could also be determined with more sophisticated methods. However, as pointed out before, it should be kept in mind whether or not all these extensions really improve the results of the model and what kind of additional information they provide.

Finally, less principal and smaller improvements still can be made as well. The two small extensions of Flood and Garber (1984a) model can be further improved. The share of domestic expenditure on non-traded goods can be estimated, instead of picked arbitrary, and the risk premium could be defined differently, for example as an interest

rate differential between government securities denominated in domestic currency and in a foreign currency.

Modeling expectations and the money demand in a more sophisticated way, together with some of the other extensions mentioned above, will make the model much more flexible and might change the linear relationship between domestic credit creation and international reserve drains of the central bank. Although the basic line of thought remains the same, the latter could help a lot in reducing the over-estimation of collapse probabilities and in determining more accurate the timing of the exchange rate collapse.

Producing improved first-generation collapse models will increase the quality of the predictions made by such a model, but will not change the basic empirical implications of these kind of models. The standard models will still predict that speculative attacks on fixed exchange rates should be preceded by growing budget deficits and accelerating rates of monetarization or comparatively fast money growth. Further, one should expect real exchange rates to become overvalued and trade deficits to increase. Finally, declining stocks of foreign reserves, rising domestic interest rates, and weakening of forward exchange rates should be observed.

The challenge for the economists in the future is to build a model that not only predicts crises if the circumstances are like mentioned above, but also predict well if an exchange rate collapse is preceded by no signs of trouble, such as expansionary fiscal policies, rapid money and credit growth, increasingly overvalued real exchange rates, and depletion of reserves. The latter could occur if the shift of monetary and fiscal policies in a more expansionary direction is observed after a rational self-fulfilling attack, like predicted by second generation collapse models. The stability of the fixed exchange rate regime is then determined by the anticipated response to speculative pressure of the authorities. Once again, the modeling of this anticipated response will be the key issue in such a model and will cause some trouble, since it is very hard to determine ex-ante expectations about the possibility of crisis induced policy change.

However, some interesting new approaches for expectations modeling have been put forward and insight on the ‘fundamental’ influences, like public debt structuring, on exchange rate formation is still improved. Furthermore, one could imagine to improve collapse models by introducing ‘psychological’ or ‘political’ variables. Analysis of the Mexican peso-crisis of 1994 showed that these kind of factors were of serious influence on market expectations and the willingness of investors to purchase Mexican securities. So, as long as one stays aware of the limited explanatory power of collapse models, this area of research still offers a lot of new, interesting and potentially very beneficial challenges to future researchers. The imperfections of this kind of models should be very well understood, but their qualities should not be forgotten and exploited as much as possible. To really achieve the latter, much more effort should be put into empirical research on this subject. Maybe even more important, however, is to change the perception of most economists that exchange rates are completely unpredictable and

should be left alone, because it would be a waste of time to put energy into trying to understand and explain exchange rate movements. It must be possible to increase our knowledge about the medium and long-term driving forces behind exchange rates and their possible collapses, because a lot of opportunities for improving the current theories and models are still open.

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**Appendix A1**

The multiplicative version of the Flood and Garber (1984b) model, extended with a risk premium in the interest rate equation, consists of the following seven equations:

$$M_t^d/Q_t = e^{a0} I_t^{a1} Y_t^{a2} \quad \text{(A1)}$$
$$Q_t = P_t^{\alpha} (P_t * S_t)^{(1-\alpha)} \quad \text{(A2)}$$
$$P_t = P_t^* S_t \quad \text{(A3)}$$
$$I_t = I_t^* (S_{t+1}/S_t) R_t \quad \text{(A4)}$$
$$M_t^s = Re_t D_t \quad \text{(A5)}$$
$$D_t = D_{t-1} e^{\mu t} e^{\epsilon t} \quad \text{(A6)}$$
$$M_t^d = M_t^s \quad \text{(A7)}$$

where all variables are defined the same as described in the paper. Then, taking logs of all variables in the model results in the following loglinear model:

$$m_t^d - q_t = a_0 - a_1 i_t + a_2 y_t \quad \text{(A1')}$$
$$q_t = \alpha p_t + (1-\alpha)(p_t^* + s_t) \quad \text{(A2')}$$
$$p_t = p_t^* + s_t \quad \text{(A3')}$$
$$i_t = i_t^* + (s_{t+1} - s_t) + r_t \quad \text{(A4')}$$
$$m_t^s = re_t + d_t \quad \text{(A5')}$$
$$d_t = d_{t-1} + \mu_t + \epsilon_t \quad \text{(A6')}$$
$$m_t^d = m_t^s \quad \text{(A7')}$$

where all lower case letters indicate a logarithm of a variable. To determine the shadow floating rate the money market equilibrium condition is used to work out the model. Substituting Eq.(2') into Eq.(1') and applying Eq.(7') yields:

$$m_t = a_0 - a_1 i_t + a_2 y_t + \alpha p_t + (1-\alpha)(p_t^* + s_t) \quad \text{(A8)}$$

and filling in Eqs.(3') and (4') gives:

$$m_t = a_0 - a_1 (i_t^* + (s_{t+1} - s_t) + r_t) + a_2 y_t + \alpha(p_t^* + s_t) + (1-\alpha)(p_t^* + s_t) \quad \text{(A9)}$$

Rewriting a little:

$$m_t = a_t - a_1(s_{t+1} - s_t) + s_t \qquad \text{(A10)}$$

where

$$a_t = a_0 - a_1(i_t^* + r_t) + a_2 y_t + p_t^* \qquad \text{(A11)}$$

Remember that $re_t = r_c$ when the exchange rate is floating and, therefore, $m_t^s = r_c + d_t$ and $\Delta m_t^s = \Delta d_t = \mu_t + \epsilon_t$. Positing that the floating exchange rate solution is of the form $\tilde{s}_t = \gamma_0 + \gamma_1 m_t$ and solving for coefficients $\gamma_0$ and $\gamma_1$, using the method of undetermined coefficients, yields:

$$E_t \tilde{s}_{t+1} = \gamma_0 + \gamma_1 E_t m_{t+1} \qquad \text{(A12)}$$

$$\tilde{s}_t = \gamma_0 + \gamma_1 m_t \qquad \text{(A13)}$$

Combining Eqs.(12) and (13) and remembering $E_t \epsilon_t = 0$ gives:

$$E_t \tilde{s}_{t+1} - \tilde{s}_t = \gamma_1 \mu_t. \qquad \text{(A14)}$$

Rewriting (10) and filling in (14) and using the method of undetermined coefficients again results in:

$$m_t = a_t - a_1 \gamma_1 \mu_t + s_t \qquad \text{(A15)}$$

or

$$s_t = a_1 \gamma_1 \mu_t - a_t + m_t \qquad \text{(A16)}$$

$$\tilde{s}_t = \gamma_0' + \gamma_1' m_t \qquad \text{(A17)}$$

where $\gamma_0' = a_1 \gamma_1 \mu_t - a_t$ and $\gamma_1' = 1$. Therefore, substituting $\gamma_1$ for $\gamma_1'$ in Eq.(16) results in an expression for the floating exchange rate in period t:

$$\tilde{s}_t = a_1 \mu_t - a_t + m_t \qquad \text{(A18)}$$

To find the next period, after collapse, exchange rate Eq.(18) is raised one period.

$$\tilde{s}_{t+1} = a_1 \mu_{t+1} - a_{t+1} + m_{t+1} \qquad \text{(A19)}$$

Now, filling in Eq. (5') and remembering $re_t = r_c$ yields:

$$\tilde{s}_{t+1} = a_1\mu_{t+1} - a_{t+1} + r_c + d_{t+1} \quad \text{(A20)}$$

Which can be rewritten to:

$$\tilde{s}_{t+1} = (1+a_1)\mu_{t+1} - a_{t+1} + r_c + d_t + \epsilon_{t+1} \quad \text{(A21)}$$

Next, to determine the probability of an exchange rate collapse it is needed to find the probability that $\tilde{s}_{t+1} \geq s_{t+1}^a$. Where $s_{t+1}^a$ is the next period controlled exchange rate. Formally:

$$\pi_t = \Pr[\tilde{s}_{t+1} \geq s_{t+1}^a], \quad \text{(A22)}$$
$$= \Pr[(1+a_1)\mu_{t+1} - a_{t+1} + r_c + d_t + \epsilon_{t+1} \geq s_{t+1}^a], \quad \text{(A23)}$$
$$= \Pr[\epsilon_{t+1} \geq s_{t+1}^a + a_{t+1} - r_c - d_t - (1+a_1)\mu_{t+1}]. \quad \text{(A24)}$$

In Eq.(24) $\epsilon_{t+1}$ represents a random disturbance with zero mean which obeys $\epsilon_{t+1} = -1/\lambda + v_{t+1}$. Therefore, Eq.(24) can be rewritten as:

$$\pi_t = \Pr[v_{t+1} \geq K_t], \quad \text{(A25)}$$

where

$$K_t = s_{t+1}^a + a_{t+1} - r_c - d_t - (1+a_1)\mu_{t+1} + 1/\lambda. \quad \text{(A26)}$$

The random variable $v_{t+1}$ is distributed exponentially with an unconditional probability density function. Therefore, the formal density function is

$$f[v_{t+1}] = \lambda e^{-\lambda v t+1}, \qquad v_{t+1} > 0,$$
$$= 0 \qquad v_{t+1} \geq 0. \quad \text{(A27)}$$

The latter means that to determine the probability of an exchange rate collapse the following expression has to be integrated:

$$\pi_t = \int_{K_t}^{\infty} \lambda e^{-\lambda v_{t+1}} dv_{t+1} \qquad \text{(A28)}$$

Finally, the expression for the probability of an collapse is derived:

$$\begin{aligned} \pi_t &= \lambda e^{-\lambda K t} && K_t \geq 0 \\ &= 1 && K_t < 0 \end{aligned} \qquad \text{(A29)}$$

The probability of an exchange rate collapse depends on the development of a range of economic variables, including domestic credit growth, the critical reserve floor, the demand for real money balances and the magnitude of unexpected credit shocks.

**Abstract**

Recent financial crises in South-East Asia, and before that in Latin America and Europe, have shown that the crash of a fixed exchange rate regime can have significant negative real effects. Theoretical models that link the probability of a collapse of a fixed exchange rate to fundamental economic values like domestic credit, the trade balance, international reserves and relative prices are now standard, but empirical testing of these models has nevertheless been very limited. This paper applies such a model to the Mexican experience between 1988-1995 and to several European currencies that participated in the European Exchange Rate Mechanism (ERM) in the 'crisis' year of 1992.

The results for the Mexican case are encouraging. Mexico experienced several periods of speculative pressure on the peso between 1988 and 1995 and the model predicts collapse probabilities larger than zero for most of them. Just before the collapse of the exchange rate in December 1994, the model indeed indicates a probability of collapse equal to one. The results for the European currencies are mixed. The speculative pressure against the Spanish peseta is predicted well. The problems with the Italian lira and the French franc were predicted as well, although the timing of the events was not perfectly indicated. For the British pound, the Belgian franc, the Irish pound and the Danish krona the model results are unconvincing.