KATHOLIEKE UNIVERSITEIT
LEUVEN

Faculty of Economics and
Applied Economics

Department of Economics

Multiple Equilibria and the Credibility of the Brazilian "Crawling Peg", 1995-1998.

by

Marco LYRIO
Hans DEWACHTER

International Economics

Center for Economic Studies
Discussions Paper Series (DPS) 99.19
http://www.econ.kuleuven.be/ces/discussionpapers/default.htm

November 1999

DISCUSSION
PAPER

Multiple Equilibria and the Credibility of the Brazilian "Crawling Peg", 1995-1998

Marco Lyrio and Hans Dewachter[*]

Abstract

This paper studies the relationship between the probability of devaluation of the Brazilian *real* and the fundamentals of the economy for the period 1995-1998. We use a model of a fixed exchange rate system that allows for multiple equilibria and, therefore, makes possible the identification of self-fulfilling speculation. The devaluation probability is computed using the "drift adjustment method". The model performs satisfactorily in tracking monthly devaluation expectations and presents some important advantages over a simple linear regression of macroeconomic variables on the devaluation probability. We do not find evidence that self-fulfilling speculation was at work in the period preceding the Brazilian currency crisis of January 1999. This suggests that the breakdown of the Brazilian managed exchange rate system was due to the deterioration of the fundamentals of the economy.

Keywords: Currency crisis; self-fulfilling speculation; multiple equilibria; Brazilian exchange rate system.

JEL Classification: F33

---

[*] We thank Paul De Grauwe for his comments which improved significantly this paper. Address: Center for Economic Studies, Katholieke Universiteit Leuven, Naamsestraat 69, 3000 Leuven, Belgium. E-mail: hans.dewachter@econ.kuleuven.ac.be and marco.lyrio@econ.kuleuven.ac.be

1. Introduction

The 1990s have provided substantial incentive for the study of currency crises. The decade started with the ERM[1] crisis of 1992-93 which was followed by crises in Mexico (1994), Asia (1997), Russia (1998), and more recently in Brazil (1999).[2] Among other possible costs, currency crises might delay the process of policy reform and jeopardize the confidence of international agents in the country's institutions. Fortunately, some researchers believe that currency crises have a significant predictable component and that early-warning systems might be developed in order to reduce their occurrence.[3]

Two main approaches can be distinguished in the academic literature on currency crises.[4] The first became known as "first-generation" or speculative-attack models of currency crisis and was due to the seminal paper of Krugman (1979) and its extensions.[5] In Krugman's model, a fixed exchange rate system becomes unsustainable due to the constant deterioration of the fundamentals. A speculative attack occurs when the government's reserves fall below a certain critical level. The crisis is therefore unavoidable and its timing predictable. The mechanical way in which the government prints money and the central bank sells reserves is one of the main focus of criticisms to the Krugman's model.

The so-called "second-generation" models try to tackle these issues. In these models, there is a conflict between the government's incentives to defend and to abandon the fixed exchange rate. Furthermore, the cost to defend a fixed rate increases with the market expectations of devaluation. This gives some support for the self-fulfilling view of speculation, since high devaluation expectations can validate themselves by making it more costly for the government to defend the fixed exchange rate system.[6]

---

[1] Exchange Rate Mechanism in the European Monetary System.

[2] The occurrence of currency crises was also significant in other periods. Esquivel and Larraín (1998) study a sample of 30 countries and find that during the period of 1976-95 at least two currency crises occurred per year. The peaks in the number of crises occurred in 1976 (following the collapse of the Bretton Woods system), 1982 (due to the debt crisis in Latin America), and 1992 (due to the instability in the European Monetary System). Latin American countries had the largest number of currency crises.

[3] Esquivel and Larraín (1998).

[4] See Flood and Marion (1998) for a review of the recent currency crises literature.

[5] Flood and Garber (1984), for instance, use simplified linear models to study the breakdown of fixed exchange regimes. Obstfeld (1986) shows that speculative attacks might be self-fulfilling and crises might occur even when the fundamentals are consistent with the fixed exchange rate.

[6] Krugman (1996) questions the theoretical robustness of the self-fulfilling view by presenting a second-generation model that does not give rise to multiple equilibria.

The reasons to defend a currency might be associated with, for instance, the belief that a fixed rate facilitates international trade and investment, or serves to improve the credibility of countries with a high-inflation history. The reasons to abandon it might be linked to a large debt burden denominated in domestic currency or to the government's desire to adopt a more expansionary monetary policy due to high levels of unemployment.[7] These models are also called "cost-benefit" models since the government can freely choose to devalue the currency if the benefits of doing so outweigh the costs.

One characteristic of these models is the attempt to determine whether a currency can be attacked without a justifiable deterioration in the fundamentals. Some models identify an intermediate range for the fundamentals where a crisis may or may not occur. Other models suggest a less important role for the fundamentals. In these models, a crisis may occur as a consequence of pure speculation against the currency. This might be caused, for instance, by herding behavior or due to contagion effects.

Jeanne (1997) proposes a model in which both the fundamental and self-fulfilling speculation might play a role in the emergence of currency crisis. Self-fulfilling speculation is possible when the structural parameters of the economy allow for multiple equilibria in market expectations and when the fundamental of the economy lies within a certain range. If multiple equilibria are not possible, market expectations are uniquely determined and their value depend on the level of the fundamental. The application of this model to the French franc crisis of 1992-93 generated interesting empirical results.

In this paper, we apply Jeanne's model to the Brazilian managed exchange rate system in effect from March 1995 until December 1998. Our main purpose is to determine the relationship between the fundamental and the devaluation probability during this period. In this way, we hope to better understand the causes of the currency crisis of January 1999. The data seems appropriate for the study since it includes two episodes of speculative attack in which there was no change in the exchange rate system and it covers a total period of almost four years.

[7] See Obstfeld (1994, 1996).

The remainder of this paper is organized as follows. The model proposed by Jeanne (1997) is presented in the next section and its estimation is described in Section 3. We estimate the model for the Brazilian experience and analyze its results in Section 4. Section 5 concludes the paper.

2. The Model

In this section, we present the model of currency crises proposed by Jeanne (1997). The model represents a country with a fixed exchange rate in which the government decides at each point in time whether or not to defend the peg. The decision depends on two factors: the state (or "mood") of the government and the net benefit it receives by keeping the peg. If the government is in a "tough" mood it will defend the currency at all costs and we assume the peg is maintained. On the other hand, if the government is in a "soft" mood it will defend the peg only if the benefits of doing so outweigh the costs. Although the mood of the government is not predictable (since it might depend on political factors), it is perfectly observable by the private sector. We assume that the probability of the government being in a "soft" mood is equal to μ and in a "tough" mood equal to $(1-\mu)$[8]. The expression for the net benefit of keeping the peg has a central role in this model. It is assumed to be of the following form:

$$B_t = b_t - \alpha\pi_{t-1} \tag{1}$$

The first term (b_t) represents the gross benefit of the fixed peg and it corresponds to the benefit obtained when the peg is perfectly credible. It is an exogenous variable that summarizes the economic situation of the country based on macroeconomic variables and is represented by:

$$b_t = E_{t-1}b_t + \varepsilon_t$$

where E_t represents the time t expectations operator and we assume the innovation ε_t to be independently and identically distributed (i.i.d.), characterized by a continuous and symmetric density function $f(\cdot)$, and strictly increasing (decreasing) in $(-\infty,0)$ $((0,+\infty))$.

[8] This is in contrast to most models of fixed exchange rate system in which it is assumed that the government is always in a "soft" mood (μ=1).

The second term (π_{t-1}) in Eq.(1) represents the probability that the currency will be devalued at time t by a certain amount *d*. This probability is evaluated by the private sector at time t-1.[9] Equation (1) represents, in fact, the logic of self-fulfilling speculation in second-generation models where the policymaker's decision of whether or not to keep the peg is affected by devaluation expectations.[10]

As mentioned before, the currency will be devalued if the government is in a "soft" mood and the net benefit of keeping the fixed peg at t+1 is negative. This allows us to express the probability of devaluation in the current period as:

$$\pi_t = \mu \, \mathrm{Prob}_t \left[B_{t+1} < 0 \right]$$

From Eq. (1) and (2), we can express the condition $B_{t+1} < 0$ as $\varepsilon_{t+1} < \alpha\pi_t - E_t b_{t+1}$ which gives:

$$\pi_t = \mu \, \mathrm{Prob} \left[\varepsilon_{t+1} < \alpha\pi_t - E_t b_{t+1} \right]$$

Due to the characteristics of ε, one can rewrite this expression in terms of the cumulative distribution of $f(\cdot)$. Although not necessary at this point (see Jeanne 1997), we assume already that $f(\cdot)$ has a normal distribution with mean zero, standard deviation σ, a and cumulative distribution represented by $F_\sigma(\cdot)$. This gives rise to the main equation of this model, being:

$$\pi_t = \mu F_\sigma (\alpha\pi_t - \phi_t) \qquad (2)$$

where ϕ_t $(= E_t b_{t+1})$ represents all the economic variables that are relevant for the determination of the devaluation probability and is denominated the "fundamental" of the economy. Observing Eq.(2), one can see that the maximum value for the devaluation probability is equal to μ since the maximum of the cumulative distribution function F_σ is equal to one. Jeanne (1997) shows that the number of solutions for this equation depends on the following parameter:

---

[9] The timing with which devaluation expectations affect the policymaker's decision seems to play an important role in second generation models. Krugman (1996) shows that if this decision is affected by devaluation expectations formed in the current period and if the fundamental deteriorates deterministically multiple equilibria do not arise. Jeanne and Masson (1998) analyze a similar case in which the net benefit depends on the current devaluation probability ($B_t = b_t - \alpha\,\pi_t$). They find that depending on certain conditions for the fundamental an arbitrarily number of equilibria may arise. They also show that when the net benefit depends on both the current and lagged devaluation probabilities, devaluation probabilities are in general not uniquely determined and might present a cyclic or chaotic dynamics.

[10] Obstfeld (1994) shows how this decision might be affected by the level of unemployment. Jeanne (1997) also uses a similar case as one way to justify the form assumed for Eq.(1).

$$z = \frac{\mu\alpha}{\sigma\sqrt{2\Pi}}$$

Multiple equilibria not possible. If $z \leq 1$ the devaluation probability is uniquely determined and decreases with the fundamental ϕ (see Fig.1 for the case when $z < 1$). The slope of the curve in Fig.1 can be interpreted as the degree of *responsiveness* of the market to a change in the fundamental of the economy. It reaches a maximum at the inflection point where $\pi_{\inf.point} = \phi_{\inf.point} = 0.5\mu$. Assuming that the parameter α is equal to one (a necessary condition for the identification of the other parameters of the model), we have that the maximum responsiveness of the market to a change in the fundamental is equal to:

$$\left.\frac{d\pi}{d\phi}\right|_{\inf.point} = \frac{-z}{1-z}$$

For practical purposes, we define a certain *critical range* for the fundamental in which the change in market expectations is greater than the change in the fundamental, i.e., the slope of the curve in Fig.1 is greater than one in absolute value. The demonstration of these results and the equations used to compute the frontiers of the critical range are presented in the Appendix.

INSERT FIGURE 1

Multiple equilibria possible. When $z > 1$ the devaluation probability may assume three different values within the interval ($\underline{\phi}, \overline{\phi}$)(see Fig.2). The possibility of self-fulfilling speculation therefore exists if $z > 1$. Outside the mentioned range, the devaluation probability is uniquely determined.[11]

INSERT FIGURE 2

Currency crisis. In this model, a currency crisis is identified when the devaluation probability suddenly increases to unusually high levels. This might happen in two cases: (i) Due to a decrease in the

[11] For the computation of the range ($\underline{\phi}, \overline{\phi}$), see Jeanne (1997).

fundamental alone ($z \le 1$); or (ii) due to self-fulfilling speculation. This might occur if $z > 1$, the fundamental is between the range ($\underline{\phi}, \overline{\phi}$) in Fig.2, and the devaluation probability jumps from a low to a high level ($\pi_1(\phi)$ to $\pi_2(\phi)$ or $\pi_3(\phi)$). Although we characterize the crisis as caused by self-fulfilling speculation, the fundamental also plays its role since it must be between the mentioned range. The actual jump in the devaluation probability is, however, caused by the "animal spirits" of the market. These might be determined by a number of different sunspot variables[12], like the behavior of important market participants or the arrival of good and bad news.

3. Estimation

The estimation of the model is done using the maximum likelihood method. The three main equations used in the estimation are as follows:

$$\phi_t = \gamma' x_t \tag{3}$$

$$\hat{\pi}_t = \mu F_\sigma(\hat{\pi}_t - \phi_t) \tag{4}$$

$$\pi_t = \hat{\pi}_t + \eta_t \tag{5}$$

In Eq.(3), we define the fundamental as a linear function of relevant macroeconomic variables and a constant (represented by the vector x_t). The coefficients of this function are included in the vector γ'. The main equation of our model (Eq.(2)) is represented in Eq.(4) (with α normalized to 1). Finally, Eq.(5) states that the observed (or inferred) devaluation probability is equal to its estimated value plus a prediction error η_t, assumed to be normally distributed with variance σ_η^2. The devaluation probability at each period (π_t) is computed based on the "drift adjustment method" proposed by Svensson (1993a).[13] This method suggests that the expected depreciation within the band should be estimated and then subtracted from the interest rate differential.

For the case of multiple equilibria ($z > 1$ and $\phi \in (\underline{\phi}, \overline{\phi})$), we need to define a variable s_t as the state (1, 2, or 3) at time t corresponding to the branches 1, 2, or 3, respectively, as shown in Fig.2. We assume that

---

[12] Sunspot variables are said to be those variables which coordinate the expectation of foreign exchange market participants.

the selection mechanism between states follows a Markov process independent of the fundamental. Observing the characteristic of branch 2 in Fig.2, we note that the devaluation probability increases with the fundamental. Since this is rather counterintuitive, we exclude state 2 (branch 2) as a possible state. The Markov Matrix can then be written as:

$$\Theta = \begin{pmatrix} \theta(1,1) & 0 & \theta(1,3) \\ 0 & 1 & 0 \\ \theta(3,1) & 0 & \theta(3,3) \end{pmatrix}$$

where $\theta(i, j)$ are the probabilities of transition from state i to state j when the fundamental is between the range $(\underline{\phi}, \overline{\phi})$. The maximum likelihood method is used in order to estimate the parameters γ, μ, and σ (or z), and the sequence of states $(s_t)_{t=1}^{T}$, based on the macroeconomic variables $(x_t)_{t=1}^{T}$ and on the devaluation probability $(\pi_t)_{t=1}^{T}$.

4. The Brazilian Experience

In this section, we apply the model outlined in Sections 2 and 3 to the Brazilian *real*[14] for the period in which this currency was subjected to a managed exchange rate system (March 1995 - December 1998). Our main purposes are: (i) To check for the presence of self-fulfilling speculation during the mentioned period; (ii) To study the relationship between the fundamental of the economy and the devaluation probability; and (iii) To determine the significant macroeconomic variables among those chosen to constitute the fundamental.

The Brazilian *real* was created as part of an economic stabilization program (the Real Plan[15]) implemented in July 1994. The government's main objective was to achieve price stability after having experienced hyperinflation from 1988 until 1994 (it reached its peak in 1993 at a level of approximately 2700%).[16] At its creation, the *real* was at parity with the dollar. Although there was no law fixing this

---

[13] See also Bertola and Svensson (1993), Rose and Svensson (1994), and Thomas (1994).

[14] We use italics to avoid confusion with the word real.

[15] See Dornbusch (1997) for a historical perspective and a more detailed discussion of the Real Plan.

[16] The adoption of fixed exchange rates as means for price stability is controversial. Svensson (1993b) points to the inherent unsustainability of fixed exchange rates and stresses its ineffectiveness as means to obtain price stability. Sachs, Tornell and Velasco (1996) also point out that pegged exchange rates might increase a country's vulnerability to speculative attacks. They do suggest, however, that pegging might be

parity with the dollar, the Central Bank announced a floor for the value of the currency at this level. The increase in capital flows caused an appreciation of the *real* by almost 20 percent (no limit was placed on currency appreciation; see Fig.3). This resulted in trade problems and on 06 March 1995 the government introduced an exchange rate system based on bands. It also announced that it would adopt a "crawling peg" system that would allow the currency to depreciate at a rate of approximately 7½ percent per year. The exchange rate and the bands set from this date until December 1998 are shown in Fig.3.

From July 1994 until December 1998 the *real* suffered three speculative attacks. The first one came in the wake of the *Mexican* crisis of 1995, the second came in October 1997 in the period after the beginning of the *Asian* crisis, and the third in the fourth quarter of 1998 during the *Russian* crisis. One could argue that these crises can be seen as a possible sunspot coordination variable. In all cases, the main policy adopted to defend the currency was to increase interest rates and to make use of international reserves (see Fig.4 and 5f, respectively).

Due to an increase in the expectations of a currency devaluation, the government and the International Monetary Fund (IMF) agreed by December 1998 on a US$41.5 billion program to help Brazil to avoid a possible devaluation. The pressure on the exchange rate market increased substantially at the beginning of 1999 and by mid-January the government decided to float the exchange rate. Two months later, the *real* had been devalued by approximately 45% relative to its value at the beginning of the year.

INSERT FIGURES 3 AND 4

Macroeconomic Data

We use monthly data from March 1995 to December 1998. The variables included in the representation of the fundamental of the Brazilian economy are: real exchange rate, unemployment, trade balance gross domestic product (GDP) ratio, inflation, government finance GDP ratio, and international reserves[17].

---

important in the early stages of stabilization programs. For the aftermath of stabilization, these authors recommend the use of a flexible crawling peg.

[17] We have used the natural logarithms of the real exchange rate and international reserves in the computations. With the exception of the unemployment level (obtained from the Brazilian Institute for Geography and Statistics), we use data from the International Financial Statistics (IFS).

We believe, as suggested by Jeanne (1997), that the inclusion of political variables in the definition of the fundamental could, in general, improve the performance of the model in explaining the probability of devaluation. The main difficulty lies in the definition of such variables in a way that avoids the trap of explaining all the observations based on ad hoc dummy political variables. One natural candidate would be the conduct of elections. In the Brazilian case, the elections at the end of 1998 might, in fact, have influenced agents' expectations regarding a change in the exchange rate policy adopted by the government. This variable was not included due to the lack of observations after the event (only one).

Figure 5a shows the overvaluation with respect to the dollar suffered by the *real* since its creation.[18] This overvaluation achieved a maximum of almost 30% in July 1996[19] and was approximately equal to 19% at the end of 1998.[20] The upward trend in unemployment can be seen in Fig.5b. Figure 5c shows that the trade balance GDP ratio has been consistently negative since mid-1996 with a slightly declining trend. Figure 5d shows a clearly declining inflation since the implementation of the Real Plan, being close to zero by the end of 1998. The government finance GDP ratio can be seen in Fig.5e. It has been negative (public deficit) most of the time and shows a slightly declining trend. Finally, the level of international reserves is presented in Fig.5f.

Devaluation Probability

The devaluation probability $(\pi_t)_{t=1}^{T}$ is derived assuming that during the period studied there was no real realignment of the central parity since the government announced in advance the use of a "crawling peg" system. This means we compute the exchange rate within the band in relation to a fixed central parity. We use the central parity of the second band established by the government (equal to 0.905R$/US$) since the first one was valid for only four days. For the interest rates, we use the Brazilian and American three-month money market rates. We also assume that the expected size of the devaluation was equal to 25%. This value was based on the average devaluation size necessary to bring the real exchange rate back to the value of one. The devaluation probability is shown in Fig.8 (curve "inferred").

---

[18] The real exchange rate is computed based on the consumer prices of Brazil and USA (IFS line 64). A decrease in this index corresponds to a real appreciation of the *real*.

[19] According to Dornbusch (1997), by 1996, the real appreciation was between 3 and 76 percent depending on the measure used.

INSERT FIGURE 5 (A) TO (F)

Empirical Results

We present the results of the estimation in Table 1, together with the results of a linear regression of the selected macroeconomic variables on the devaluation probability. The linear regression might also be seen as the estimation of the model presented earlier with Eq.(4) being replaced by $\hat{\pi}_t = \phi_t$.

The value of 0.9 obtained for the parameter z indicates that the devaluation probability is uniquely determined for all values of the fundamental ($z < 1$). Since multiple equilibria are not possible, we can exclude the possibility of self-fulfilling speculation during the period studied. The estimated value for μ indicates that the government was in a "soft" mood during approximately 19% of the time.

For the non-linear case (Jeanne's model), the expected signs for the coefficients of the macroeconomic variables are determined by their expected influence on the fundamental ϕ (see Eq.(3)). We expect, therefore, a positive sign for the coefficients of real exchange rate, trade balance GDP ratio, government finance GDP ratio, and reserves, since the fundamental should be increasing with these variables. The opposite is expected for the levels of unemployment and inflation. In the linear case, the expected signs for the coefficients are determined based on their influence on the devaluation probability (in this case $\hat{\pi}_t = \gamma' x_t$). The expected signs are, therefore, opposite to those assigned in the case of Jeanne's model.

Table 1 shows that, for the non-linear case, the level of international reserves is the only variable that is significant and has the expected sign. This points to the importance of this variable in the determination of the fundamental of the Brazilian economy. A similar result is obtained with the linear regression. In this case, however, the level of inflation is also significant (with the right sign) and the real exchange rate and the trade balance GDP ratio are significant at 10% level but with the wrong sign.

---

[20] Goldfajn and Valdés (1996) study a sample of 93 countries from 1960 until 1994 and conclude that it is relatively unlikely to undo appreciations greater than 25%.

The evolution of the estimated fundamental can be seen in Fig.7. Fig.9 shows the separate contribution of each macroeconomic variable in the composition of the fundamental. One can see clearly the importance of the level of international reserves in this composition, in accordance with the empirical results presented in Table 1. Observing Fig.7, we see that the fundamentals of the Brazilian economy were within this critical range for the entire period analyzed. This points to the vulnerability of the currency to changes in the fundamental.

Figure 8 shows that both models perform reasonably well in tracking the general trend of monthly devaluation expectations.[21] By visual inspection, though, it does not seem obvious which model performs better. Examining the loglikelihoods, we can see that the non-linear model performs better than the linear regression. However, since these are non-nested models, we cannot apply a LR test to assess the significance of the difference in the performance of the two models.

Comparison

Although we mentioned that the linear regression performed almost as well as Jeanne's model, we should stress that the latter still contains some important advantages over the linear model. First, it makes possible the identification of self-fulfilling speculation. Second, it allows us to compute the level of the fundamental and monitor its value with respect to a certain critical range. Third, the model always provides a value for the devaluation probability between the range zero and one. It defines, in fact, a maximum for the devaluation probability equal to μ. This is not the case in a linear regression where unusual values for a macroeconomic variable could lead to values above one or negative. The main advantage of the linear regression is the fact that it is simple and straightforward to estimate. Besides, we expect Jeanne’s model to present a higher performance in cases with multiple equilibria.

INSERT TABLE 1

INSERT FIGURES 6 TO 9

[21] The probability of the currency *not* being devalued in the following n months is equal to $(1-\pi)^n$. This means that for a devaluation probability equal to 16%, for example, there is a 12% chance that the currency will not be devalued in the following year.

5. Conclusion

We have used a model of a fixed exchange rate system that allows for multiple equilibria to study the relation between the probability of devaluation of the Brazilian *real* and the fundamental of the economy. We have focused on the period from March 1995 until December 1998 during which the currency was subjected to a managed exchange rate system. We have shown that the structural parameters of the economy did not allow for the presence of multiple equilibria. There is, therefore, no evidence of self-fulfilling speculation during the period studied. This leads us to conclude that the Brazilian currency crisis of January 1999 was caused by a deterioration of the fundamental.

It was also shown that the model performs quite well in predicting devaluation expectations. Although its performance is apparently not significantly better than the linear regression, we were able to show some important advantages of this model. Furthermore, we expect the performance of the model to be superior to the linear regression in cases where multiple equilibria are possible, as in Jeanne (1997).

In the Brazilian case, we showed that the fundamental was within a defined critical range for almost the entire period analyzed. This indicates the vulnerability of the Brazilian *real* with respect to changes in the fundamental. The level of international reserves was found to be the only significant macroeconomic variable in the representation of the fundamental for which the expected sign was obtained. This points to the importance of this variable in the policy adopted by the government to defend the currency in periods of crises.

References

Bertola, Giuseppe, and Lars E. O. Svensson (1993), 'Stochastic Devaluation Risk and the Empirical Fit of Target-Zone Models', *Review of Economic Studies*, 60, 689-712.

Dornbusch, Rudiger (1997), 'Brazil's Incomplete Stabilization and Reform', Brookings Papers on Economic Activity 1, Brookings Institution, 367-404.

Esquivel, Gerardo, and Felipe Larraín B. (1998), 'Explaining Currency Crises', mimeo, Harvard Institute for International Development.

Flood, Robert P., and Nancy Marion (1998), 'Perspectives on the Recent Currency Crisis Literature', NBER Working Paper No.6380.

Flood, Robert P., and Peter M. Garber (1984), 'Collapsing Exchange-Rate Regimes - Some Linear Examples', *Journal of International Economics*, 17, 1-13.

Goldfajn, Ilan, and Rodrigo O. Valdés (1996), 'The Aftermath of Appreciations', NBER Working Paper No.5650.

Jeanne, Olivier (1997), 'Are Currency Crises Self-fulfilling? A Test', *Journal of International Economics*, 43, 263-286.

—— (1998), 'Currency Crises, Sunspots and Markov-Switching Regimes', CEPR Discussion Paper Series, No.1990.

Krugman, Paul (1979), 'A Model of Balance-of-payment Crises', *Journal of Money, Credit and Banking*, 11 (August), 311-25.

—— (1996), 'Are Currency Crises Self-Fulfilling?', NBER Macroeconomics Annual, 345-378.

Obstfeld, Maurice (1986), 'Rational and Self-fulfilling Balance of Payment Crises', *American Economic Review*, 76 (March), 72-81.

—— (1994), 'The Logic of Currency Crises', *Cahiers Economiques et Monétaires*, 43, 189-213.

—— (1996), 'Models of Currency Crises with Self-fulfilling Features', *European Economic Review*, 40, 1037-1047.

Rose, Andrew K., and Lars E. O. Svensson (1994), 'European Exchange Rate Credibility Before the Fall', *European Economic Review*, 38, 1185-1216.

Sachs, Jeffrey D., Aarón Tornell, and Andrés Velasco (1996), 'The Mexican Peso Crisis: Sudden Death or Death Foretold?', *Journal of International Economics*, 41, 265-283.

Svensson, Lars E. O. (1993a), 'Assessing Target Zone Credibility - Mean Reversion and Devaluation Expectations in the ERM, 1979-1992', *European Economic Review*, 37, 763-802.

—— (1993b), 'Fixed Exchange Rates as a Means to Price Stability: What Have We Learned?', NBER Working Paper No.4504.

Thomas, Alun H. (1994), 'Expected Devaluation and Economic Fundamentals', *Staff Papers*, International Monetary Fund, 41, No.2 (June), 262-285.

Appendix

In order to compute the degree of *responsiveness* of the market to a change in the fundamental of the economy, we need to determine the slope of the curve ($\frac{d\pi}{d\phi}$) in Fig. 1.[22] From Eq.(2) ($\pi = \mu F_\sigma(\alpha\pi - \phi)$), we have that:

$$\frac{d\pi}{d\phi} = \mu \frac{dF_\sigma(\alpha\pi - \phi)}{d\phi} = \mu \frac{dF_\sigma(\alpha\pi - \phi)}{d(\alpha\pi - \phi)} \frac{d(\alpha\pi - \phi)}{d\phi} = \mu f(\alpha\pi - \phi)\left(\frac{d(\alpha\pi)}{d\phi} - 1\right)$$

$$\frac{d\pi}{d\phi} = \mu f(\alpha\pi - \phi)\frac{d(\alpha\pi)}{d\phi} - \mu f(\alpha\pi - \phi)$$

$$\frac{d\pi}{d\phi} = \frac{-\mu f(\alpha\pi - \phi)}{1 - \mu\alpha f(\alpha\pi - \phi)} \qquad \text{(A1)}$$

It is interesting to know for what value of the fundamental this variation is maximum. In other words, at what point the market reacts most strongly to a change in the fundamental. We should, then, compute the value of the fundamental that satisfies the equation $\frac{d^2\pi}{d\phi^2} = 0$. This condition is satisfied at the *inflection point* of the curves in Fig.1. Taking the derivative of Eq.(A1) yields:

$$\frac{d^2\pi}{d\phi^2} = \frac{-\mu \frac{df(\alpha\pi - \phi)}{d\phi}(1 - \mu\alpha f(\alpha\pi - \phi)) + \mu f(\alpha\pi - \phi)\left(-\mu\alpha \frac{df(\alpha\pi - \phi)}{d\phi}\right)}{(1 - \mu\alpha f(\alpha\pi - \phi))^2}$$

$$\frac{d^2\pi}{d\phi^2} = \frac{-\mu \frac{df(\alpha\pi - \phi)}{d\phi} + \mu^2\alpha f(\alpha\pi - \phi)\frac{df(\alpha\pi - \phi)}{d\phi} - \mu^2\alpha f(\alpha\pi - \phi)\frac{df(\alpha\pi - \phi)}{d\phi}}{(1 - \mu\alpha f(\alpha\pi - \phi))^2}$$

$$\frac{d^2\pi}{d\phi^2} = \frac{-\mu \frac{df(\alpha\pi - \phi)}{d\phi}}{(1 - \mu\alpha f(\pi - \phi))^2} \qquad \text{(A2)}$$

Equation (A2) is equal to zero when:

$$\frac{df(\alpha\pi - \phi)}{d\phi} = \frac{df(\alpha\pi - \phi)}{d(\alpha\pi - \phi)} \frac{d(\alpha\pi - \phi)}{d\phi} = \frac{df(\alpha\pi - \phi)}{d(\alpha\pi - \phi)}\left(\frac{d(\alpha\pi)}{d\phi} - 1\right) = 0$$

[22] This analysis is not included in Jeanne (1997).

This is possible if either $\frac{df(\alpha\pi-\phi)}{d(\alpha\pi-\phi)}=0$ or $\frac{d(\alpha\pi)}{d\phi}=1$. We assume now that α=1. As mentioned before, this is a necessary condition for the identification of the other parameters of the model. Under this assumption, the second condition is not possible since the slopes of the curves in Fig.1 is always negative. So, we need to find the value for φ that satisfies the first condition. Due to the characteristics of $f(\cdot)$, this happens at the point zero, or when $\phi=\pi$. Returning to our Eq.(2), with α=1 ($\pi=\mu F_\sigma(\pi-\phi)$), we have that at this point the cumulative distribution function F_σ is equal to 0.5. So, the inflection point happens when:

$$\pi_{inf.point}=\phi_{inf.point}=0.5\mu$$

We can now compute the slope of the curve at the inflection point. Making $\phi=\pi$ in Eq.(A1) and keeping our assumption of α=1 yields:

$$\left.\frac{d\pi}{d\phi}\right|_{inf.point}=\frac{-\mu f(0)}{1-\mu f(0)}=\frac{-\mu\frac{1}{\sigma\sqrt{2\Pi}}}{1-\mu\frac{1}{\sigma\sqrt{2\Pi}}}=\frac{-z}{1-z}$$

In order to compute the bounds of the critical range, we first add φ to both sides of Eq.(2) and obtain:

$$\pi+\phi=\mu F_\sigma(\pi-\phi)+\phi$$

or $$\phi=\mu F_\sigma(\pi-\phi)-(\pi-\phi) \qquad \text{(A3)}$$

We make now Eq.(A1) equal to -1:

$$\frac{-\mu f(\pi-\phi)_{slope=-1}}{(1-\mu f(\pi-\phi)_{slope=-1})}=-1$$

$$-\mu f(\pi-\phi)_{slope=-1}=-(1-\mu f(\pi-\phi)_{slope=-1})$$

and $$f(\pi-\phi)_{slope=-1}=\frac{1}{2\mu}$$

Making the normal distribution function equal to 1/(2μ) yields:

$$\frac{1}{2\mu}=\frac{1}{\sigma\sqrt{2\Pi}}\exp\left\{-\frac{1}{2}\left(\frac{(\pi-\phi)_{slope=-1}}{\sigma}\right)^2\right\}$$

$$(\pi-\phi)_{slope=-1}=\pm\sqrt{-2\sigma^2\ln\left(\frac{\sigma\sqrt{2\Pi}}{2\mu}\right)} \qquad \text{(A4)}$$

Substituting the positive value resulting from Eq.(A4) ($\pi > \phi$, the point is to the left of the inflection point) in Eq.(A3) gives us the lower bound (R_L) of the critical range which includes the points with a slope higher than one in absolute value. The upper bound (R_U) is obtained using the negative value resulting from Eq.(A4).

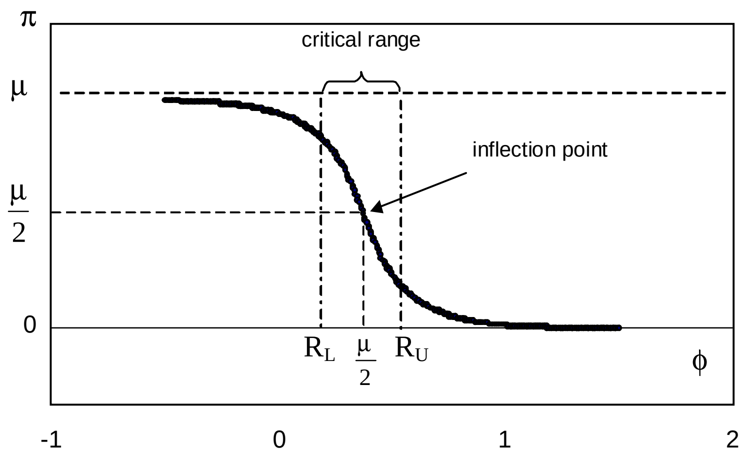


Figure 1. Devaluation probability vs. fundamental for $z < 1$

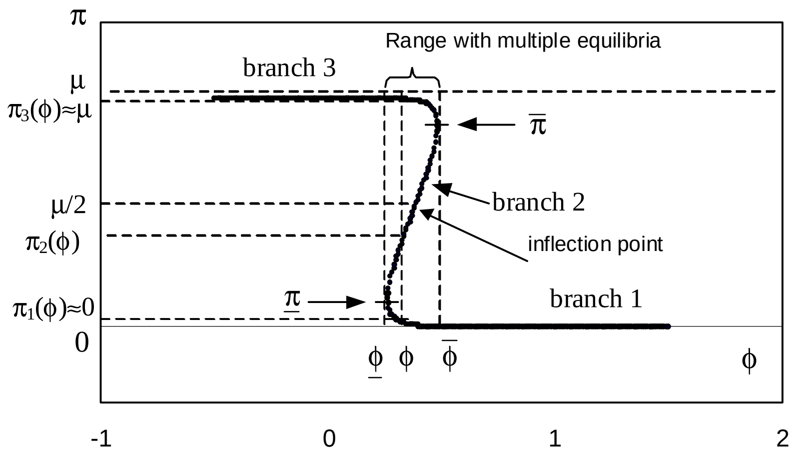
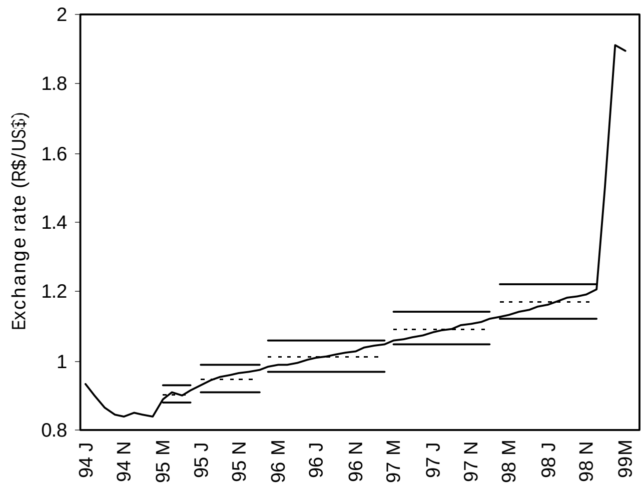
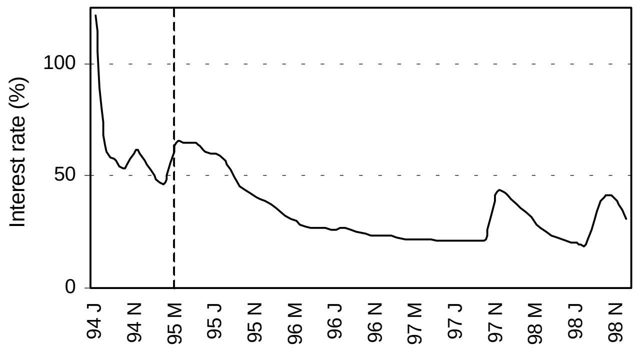


Figure 2. Devaluation probability vs. fundamental for $z > 1$



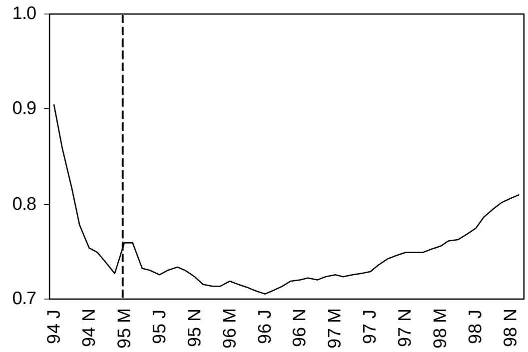
Source: IFS (line rf) and Central Bank of Brazil, monthly data.

Figure 3. Exchange rate, July 1994 - March 1999



Source: IFS (line 60b), monthly data.
Vertical dashed line: start of "crawling peg" system

Figure 4. Interest rate (money market rate), July 1994 - Dec. 1998



Source: IFS (lines rf, 64 Brazil, 64 USA)

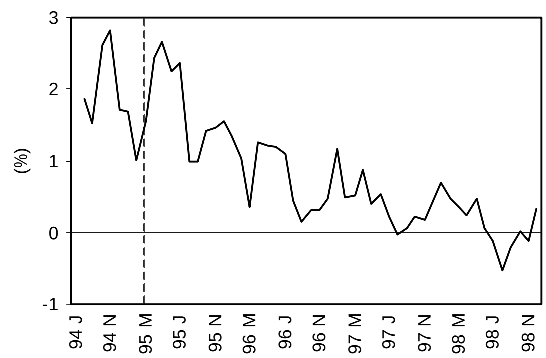
(a) Real exchange rate (July 1st,1994=1)

Source: IBGE (Brazilian Institute of Geography and Statistics)

(b) Unemployment

Source: IFS (lines 70d, 71vd, 99b, and rf)

(c) Monthly trade balance/GDP ratio

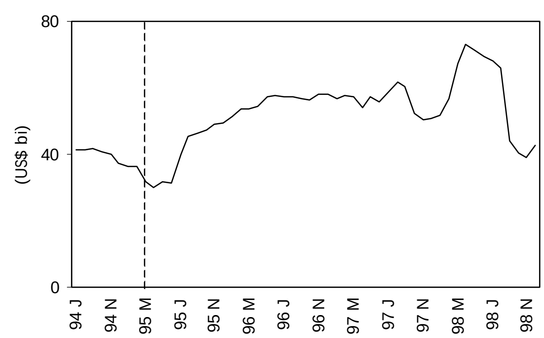


Source: IFS (line 64)

(d) Monthly inflation

Source: IFS (lines 80 and 99b)

(e) Monthly government finance/GDP ratio



Source: IFS (line 11d)

(f) International reserves (total reserves minus gold)

Figure 5. Macroeconomic data, July 1994 - Dec. 1998, monthly data

Vertical dashed line: start of "crawling peg" system

Table 1. Empirical Results

	Model (non-linear case)		Linear regression	
	Expected sign	Value[1]	Expected sign	Value[1]
Constant		-0.3633**		1.4828**
Ln RER	+	0.02621	-	0.25771*
Unemployment	-	0.0004827	+	-0.0025048
Trade balance/GDP	+	-0.01340	-	0.07580*
Inflation	-	-0.0005685	+	0.0150290**
Gov.finance/GDP	+	-0.00353	-	0.01155
Ln Reserves	+	**0.042969*****	-	**-0.122406*****
Ln L		131.07		126.25
z ($H_0 : z = 1$)		0.9046***		
μ (prob. gov. "soft" mood)		0.1865		
σ		0.08224		

* significant at 10% level.
** significant at 5% level.
*** significant at 1% level.

[1] The high non-linearity of the problem imposes difficulties in the determination of the standard errors of the estimated coefficients. The significance of the coefficients is then estimated based on the Likelihood Ratio (LR) which is equal to $LR = -2(\ln L_R - \ln L)$. The terms $\ln L_R$ and $\ln L$ represent the maximum log-likelihood of the constrained and unconstrained estimates, respectively.

Note: Real exchange rate (July 1st, 1994=1); Unemployment (%); Monthly trade balance GDP ratio (%); Monthly inflation (%); Monthly government balance GDP ratio (%); International reserves (US$ million).

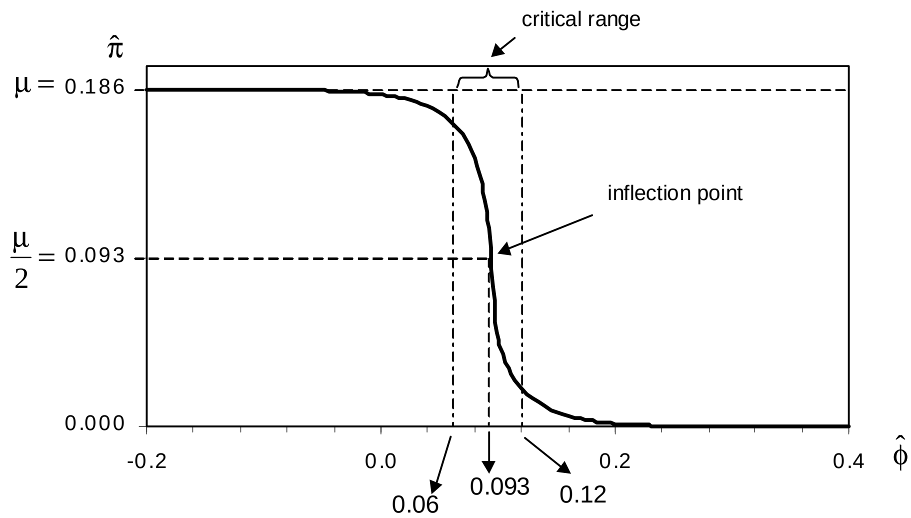


Figure 6. Probability of devaluation vs. fundamental - Brazilian case
max. slope (at inflection point)=-9.5

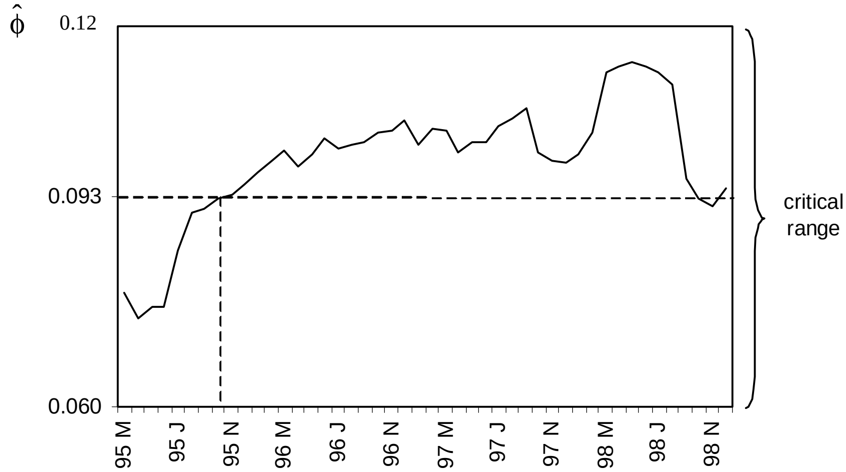


Figure 7. Estimated fundamental, March 1995 - Dec. 1998

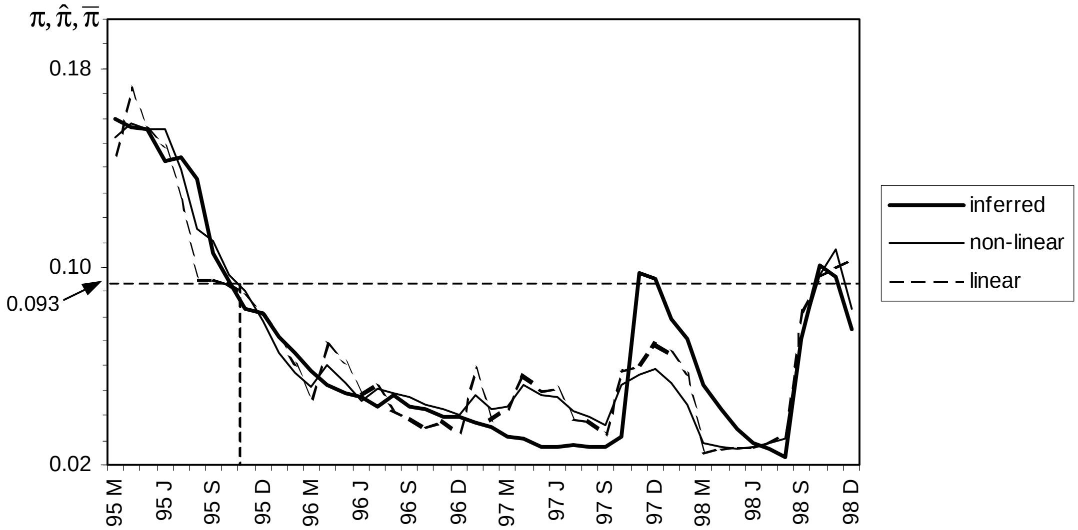
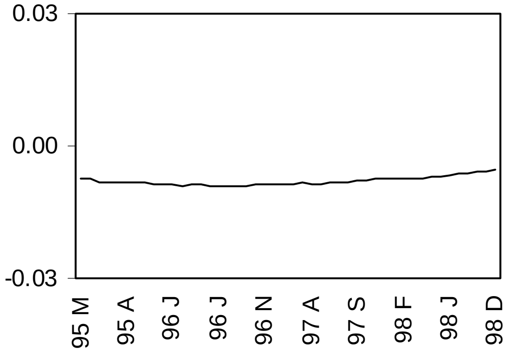
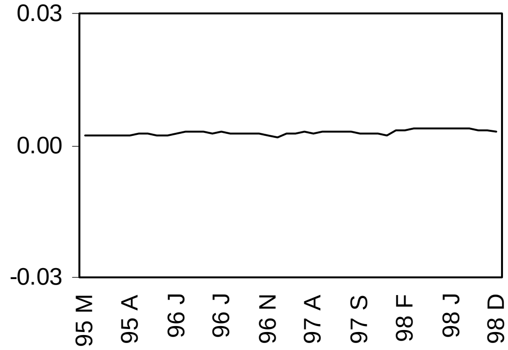


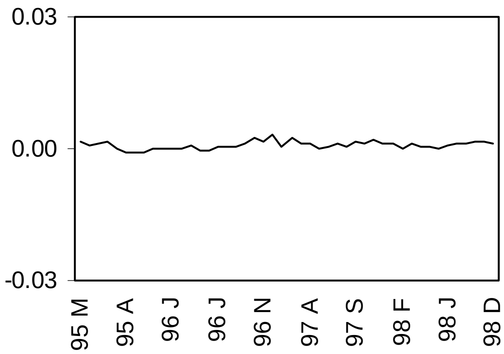
Figure 8. Monthly probability of devaluation, March 1995 - Dec. 1998



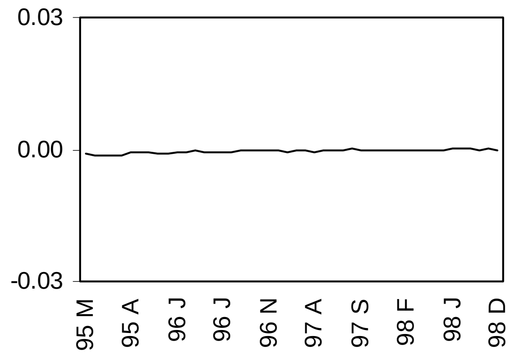
(a) ln RER



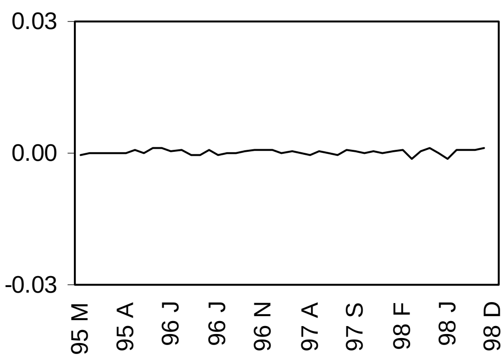
(b) Unemployment



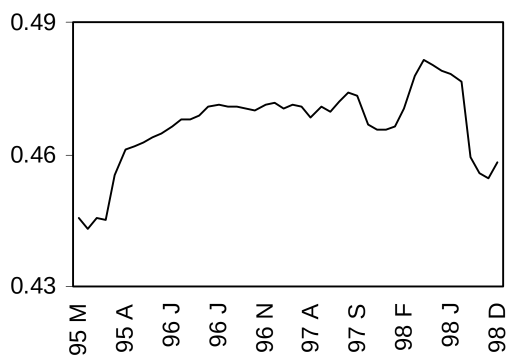
(c) Trade balance/GDP



(d) Inflation



(e) Gov.finance/GDP



(b) ln Reserves

Figure 9. Componentes of the estimated fundamental, March 1995 - Dec. 1998