Are currency crises self-fulfilling?
A test

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Abstract

This paper studies the respective roles of the fundamentals and self-fulfilling speculation in currency crises. We first present a model of a fixed exchange rate system in which self-fulfilling speculation can arise following a bifurcation in the fundamentals. We then estimate the model in the case of the 1992–3 crisis of the French franc, and find some evidence that self-fulfilling speculation was at work.

Keywords: Currency crisis; Speculation; Multiple equilibria; European Monetary System

JEL classification: F33

1. Introduction

The recent instability of several fixed exchange rate arrangements has revived old debates about the role of fundamentals in foreign exchange speculation. On the one hand, it may be argued that the crises that shook the European Monetary System (EMS) in 1992–3 or the Mexican peso in 1994 were associated with weak and deteriorating fundamentals.\(^1\) What seems puzzling, on the other hand, is that in

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\(^1\)Admittedly the relevant fundamentals were not the same for the different currencies involved in those crises. While currencies like the Mexican peso or the Italian lira suffered from real overvaluation, other currencies, like the French franc, were weakened by the rising cost in terms of unemployment of pursuing the fixed exchange rate objective. There is a large literature analysing the developments and causes of these crises: see, e.g., Eichengreen and Wyplosz (1993) on the EMS crisis and Calvo and Mendoza (1996) for the Mexican peso.
both cases speculation emerged so suddenly and unexpectedly, even though the economic conditions had been deteriorating progressively and predictably for some time (Rose and Svensson, 1994; Obstfeld and Rogoff, 1995). While the apparent shortsightedness of speculators may be attributed to irrationality, some economists have argued that it may also be explained by rational self-fulfilling “animal spirits” (Eichengreen and Wyplosz, 1993; Obstfeld, 1996; Obstfeld and Rogoff, 1995).

Whether speculation may be motivated by “market spirits” or not has important policy implications. It determines to a large extent the attitude towards speculation that economists recommend to governments. Those who think that speculation is self-fulfilling view fixed exchange rate systems as intrinsically unstable, vulnerable to erratic speculative movements. They tend to advocate measures of capital controls which might help the governments to defend their currencies. For example, Eichengreen et al. (1995b) propose the introduction of a “Tobin tax” on foreign exchange transactions in order to rebuild a new, more stable, EMS. On the other hand, those who think that speculative movements are due to the fundamentals tend to adopt a more positive view of speculation. According to them, the adequate way to avoid currency crises is to implement fiscal and monetary policies which make the commitment to the exchange rate objective credible. When this is not the case, the speculation plays a useful disciplinary role by bringing home to the governments that they should adjust their fiscal and monetary policies. From this point of view, measures of capital control should be dismissed as a futile attempt to “kill the messenger”.

The theoretical literature about currency crises now provides a number of models which rationalize both views of speculation. Starting from the seminal contribution of Krugman (1979), one strand of this literature views currency crises as speculative attacks, i.e., runs on the foreign exchange reserves at the central bank. Some papers show how speculative attacks occur when the fundamentals are “bad”, i.e., the monetary policy is inconsistent with the long term maintenance of the fixed peg (Krugman, 1979; Flood and Garber, 1984a). In an important contribution, Obstfeld (1986) showed that a speculative attack may occur even if the fundamentals are consistent with the fixed parity, provided that monetary policy is expected to be looser after the peg has been abandoned. In the latter case, the speculation against the currency is self-fulfilling.

A more recent strand of the literature analyses currency crises in the context of fixed exchange rate systems with escape clauses (Obstfeld, 1991, 1994; Isard, 1995, chapter 9). In escape clause models, the credibility of the peg is determined

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2To some extent, this optimistic view of speculation inspires the Maastricht treaty. The Treaty stipulates that a currency can participate in the Monetary Union only if it could stay in the margins of the ERM during the preceding two years without the help of capital controls. This criterion relies implicitly on the idea that the speculation will select the “virtuous” currencies.

3See also Flood and Garber (1984b) and Grilli (1986).
by the expectations of the foreign exchange market about the incentives of the
government to stay in the system or opt out. The fundamentals may include a
priori all the macroeconomic variables which influence the temptation of the
government to opt out. The escape clause approach counts a growing number of
contributions, which are often motivated by the recent EMS crises. Some of them
show that fixed exchange rate systems can break down because of adverse
macroeconomic shocks (Andersen, 1994; Masson, 1995; Buitter et al., 1995; Ozkan
and Sutherland, 1994), while others stress the role of self-fulfilling speculation
(Obstfeld, 1994, 1996; Bensaid and Jeanne, 1997; Velasco, 1996; Sachs et al.,
1996).4

The purpose of this paper is to make some progress in the debate between the
view that speculation is motivated by the fundamentals and the view that it is
self-fulfilling. Rather than opposing these two views, we shall attempt to reconcile
them by showing how the fundamentals and animal spirits may complement each
other in the genesis of speculation. The analysis is based on a model that
encompasses both views, i.e., in which speculation may be fundamental-based
and/or self-fulfilling. The logic of the self-fulfilling speculation, as in recent
escape clause models with optimizing policymakers, is that the speculation makes
it more costly for the policymaker to stay in the system. An important property of
our model is that self-fulfilling market spirits cannot arise under arbitrary
circumstances, but only when the fixed exchange rate arrangement has been
undermined by weak fundamentals. Thus, both the fundamentals and the animal
spirits have a role to play in the ignition of the crisis: while the deterioration of the
fundamentals prepares the ground for speculation, the occurrence and precise
timing of the crisis is determined by animal spirits. At the mathematical level, the
interesting properties of our model results from a phenomenon of bifurcation that
may arise when the fundamentals change over time. While the market expectations
are uniquely determined for some range of fundamentals, the fundamentals may
also enter a zone in which multiple equilibria arise. When the fundamentals cross
the frontier of multiplicity, the economy bifurcates. We show that such bifurcations
can arise only when the structural parameters of the model satisfy a condition that
we state explicitly.

Because our model gives specific and complementary roles to the fundamentals
and animal spirits, it can help us to discriminate between the two at the empirical
level. Estimating the model can allow us to disentangle the effect of the
fundamentals from that of animal spirits in specific episodes of speculation. One
simply needs to see whether the estimated parameters satisfy the condition
ensuring the possibility of bifurcation, and whether the estimated fundamentals did
enter the range with multiple equilibria. To illustrate, we estimate our model in the
case of the French franc in the period 1991–3. This case is especially interesting

4A comparative review of the speculative attack and the escape clause approaches may be found in
since the French franc was subject to several episodes of speculation to which it resisted successfully, so that the data contain many interesting events without a change of regime. We find evidence that while the different episodes of crisis were associated with bad fundamentals, they were considerably aggravated by self-fulfilling speculation. Our findings confirm the assessment by several authors that the French franc crisis is a typical example of a crisis in which self-fulfilling speculation was important (Eichengreen and Wyplosz, 1993; Obstfeld and Rogoff, 1995).

The empirical part of this paper is closely related to the empirical literature studying the link between the fundamentals and the credibility of EMS currencies (Chen and Giovannini, 1994; Rose and Svensson, 1994; Caramazza, 1993; Thomas, 1994; Eichengreen et al., 1995a). This literature has produced a number of linear regressions of the devaluation expectations on a variety of macroeconomic variables, and generally failed to uncover a significant relationship between them. Rose and Svensson (1994) reach the distressing conclusion that “exchange rate realignment expectations generally appear to be relatively disconnected from macroeconomic phenomena, to a degree that is disconcerting from an economist’s point of view” (p.1186). Our paper provides an interpretation of the apparent weak correlation between the fundamentals and the devaluation expectations in the EMS. We show that a model in which the relationship between the fundamentals and devaluation expectations is non-linear, and may give rise to multiple equilibria, gives a better account of the data than the usual linear relationship that has been tested in the literature.

The paper is organized as follows. Section 2 presents the model and Section 3 the estimation method. We analyse the French franc crisis of 1992–3 in Section 4 and conclude with Section 5.

2. A stylised model of currency crises

2.1. Assumptions

We consider the situation of a country which seeks to peg its currency at a fixed rate with a foreign currency. At each time \( t \), the domestic policymaker\(^5\) can defend the peg, possibly at some cost, or abandon it. We assume that the policymaker may be in a “soft” mood with probability \( \mu \) and in a “tough” mood with probability \( 1 - \mu \). When he is in a tough mood, the policymaker maintains the peg whatever the circumstances. When he is in a soft mood, he maintains the peg only if the net benefit of doing so is strictly positive, and opts out in the opposite case. The assumption that the policymaker has a stochastic type may be justified by the same

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\(^5\) Hereafter, we denote the authority deciding whether or not to maintain the peg as the “policymaker”, leaving aside the question of the allocation of power between the government and the central bank.
reasons as those given, e.g., by Cukierman and Meltzer (1986). The relative importance assigned to the fixed exchange rate peg may shift in unpredictable ways as “individuals within the decision-making body of government change their positions, alliances and views”. Most models of fixed exchange rate systems with an escape clause assume that the policymaker is always in the soft mood, i.e. \( \mu = 1 \). Assuming that \( \mu \) may be smaller than one is not important for the theoretical part of the present paper, but turns out to be useful in the estimation of the model.

We assume that the net benefit of maintaining the peg can be decomposed into two terms:

\[
B_t = b_t - \alpha \pi_{t-1}
\]

where \( b_t \) is the gross benefit of the fixed peg, and \( \pi_{t-1} \) is the probability evaluated by the private sector at \( t-1 \) that the policymaker opts out at \( t \). Equation (1) aims to express as simply as possible the idea that at any point in time, the benefit of a fixed peg depends not only on the objective economic conditions, but also on the credibility of the policymaker’s commitment to the fixed peg. The objective economic conditions are summarized in variable \( b \), which corresponds to the benefit of the fixed peg assuming that it is perfectly credible. Presumably, the benefit \( b \) is determined at any given period by macroeconomic variables like the real exchange rate, the trade balance, or the unemployment rate. The second term of equation (1) implies that for given objective economic conditions, a lower credibility (i.e. a higher \( \pi \)) reduces the benefit of the peg. There are a number of channels through which a lower credibility may constrain the policymaker to take costly actions, for example by forcing him to increase the interest rate. To illustrate, in the next section we give an example in which the cost of low credibility is unemployment.

The only exogenous variable at date \( t \) is the gross benefit \( b_t \), which summarizes all the objective economic conditions. As far as \( b \) is concerned, we shall make the minimal assumption that the innovation in \( b \) is independently and identically distributed. More precisely, denoting \( \phi_t = E_t b_{t+1} \), we assume that:

\[
\epsilon_t = b_t - \phi_{t-1}
\]

is i.i.d., characterized by a density function \( f(\cdot) \) which is continuous, symmetric (i.e. \( \forall \epsilon, f(-\epsilon) = f(\epsilon) \)), and strictly increasing (decreasing) in \((-\infty, 0) ((0, +\infty)\).

\*Note that while the mood of the policymaker is stochastic, it is perfectly observable by the private sector at a given period. By contrast with the literature stressing the benefits of reputation, the policymaker’s mood is not a hidden variable about which the private sector learns.

\*In Jeannie and Masson (1996), we study the properties of the present model when the net benefit depends on the current period devaluation probability instead of the lagged one, i.e. \( B_t = b_t - \alpha \cdot \pi_t \). When the net benefit depends on both current and lagged devaluation probabilities, more complex (chaotic and cyclical) dynamics can arise. The form of the equilibria when the benefit (netbenefit) is made intertemporal remains to be studied.
These assumptions are satisfied for a wide class of bell-shaped density functions, including the normal.

2.2. The benefit of the fixed peg

Taken together, the assumptions that we have stated above constitute all that we need to develop our analysis. While the model of the fixed exchange rate arrangement that they constitute is very a-structural, there are a number of ways to ground the analysis in more structural models of the economy. In order to illustrate this point, we present a simple model in the spirit of Obstfeld (1991; 1994) in which the benefit of the fixed exchange rate system can be written like (1). It should be clear, however, that the assumptions that we are going to present now are not maintained assumptions of our analysis, but simply one way to justify Eq. (1).8

Let us assume that the policymaker decides whether to opt out or not by minimizing at each date t the loss function:

\[ L_t = u_t^2 + \delta_t C_t \]

where \( \delta_t \) is a dummy variable which is equal to 1 if the policymaker opts out and 0 if not, \( u_t \) is the deviation of the unemployment rate from its natural level, and \( C_t \) is the opting out cost at time t. The opting out cost may have several sources, which have been abundantly discussed in the literature. An important source of cost is the loss of reputation or credibility. This argument has been developed particularly in the literature about the EMS, which has sometimes been interpreted as a means for countries like France or Italy to anchor their deflationary policy to the credibility of the Bundesbank (Giavazzi and Giovannini, 1989).

We assume that the unemployment rate is determined by:

\[ u_t = \rho u_{t-1} - a[e_t - E_{t-1}(e_t)] \]

This relationship may be derived from an expectations augmented Phillips curve combined with an instantaneous purchasing power parity assumption, like in Isard (1995, ch.9) or Obstfeld (1994). The term \( \rho u_{t-1} \) reflects some persistence in the determination of unemployment, like in Drazen and Masson (1994) or Masson (1995), which may be due to some rigidity in the labor market.

We assume that when the government opts out, the domestic currency is devalued by an amount \( \Delta e \). The temptation to opt out thus comes from the decrease in the unemployment level which may be obtained by a devaluation. If the government devalues at \( t \), the unemployment rate will be given by:

\[ u_t = u_t^d = \rho u_{t-1} - (1 - \pi_{t-1})a\Delta e \]

In Jeanne (1995), I present another model yielding equation (1), in which the cost of devaluation expectations comes from higher ex post real interest rates.
while if it does not:

\[ u_r = u_r^d = u_r^d + a\Delta e \]

The net benefit of the fixed peg consists in the difference:

\[ B_r = L_r^d - L_r^f = C_r + (u_r^d)^2 - (u_r^f)^2 = C_r - 2\rho a\Delta e u_{r-1} + (a\Delta e)^2 - 2(a\Delta e)^2 \pi_{r-1} \]

which can be rewritten like (1) with:

\[ \alpha = 2(a\Delta e)^2 \]

\[ b_r = C_r - 2\rho a\Delta e u_{r-1} + (a\Delta e)^2 \]

The gross benefit of the fixed peg is a linear function of the unemployment rate and the opting out cost. The latter may depend on other macroeconomic variables, like the real exchange rate or the trade balance.

2.3. Multiple equilibria

An equilibrium is a fixed point in the reciprocal mapping between the beliefs of foreign exchange market participants and the policymaker’s actions. Market expectations must be rational given the policymaker’s behaviour and conversely, the opting out rule of the policymaker must be optimal given the market expectations.

Because of the rationality of the expectations, the devaluation probability at time \( t \) must be equal to the probability that the government is soft and the net benefit is negative at \( t + 1 \), i.e.:

\[ \pi_r = \mu \text{Prob}[B_{r+1} < 0] \]

where the probability is conditioned on the information available at \( t \).

Using Eqs. (1) and (2), this equation may be rewritten:

\[ \pi_r = \mu \text{Prob}[\epsilon_{t+1} < \alpha \pi_r - \phi_t] \]

or:

\[ \pi_r = \mu F(\alpha \pi_r - \phi_t) \quad \text{(3)} \]

where \( F(\cdot) \) denotes the cumulative distribution of \( f(\cdot) \).

Eq. (3) is the central equation of our model. It shows that the variable \( \phi_t \) summarizes all the exogenous state variables that matter for the determination of the devaluation probability at time \( t \). Thereafter, we shall call \( \phi_t \) the "fundamental" at date \( t \).

As both sides of Eq. (3) are increasing with \( \pi_r \), it may have multiple solutions, which means that a given level of the fundamental \( \phi \) may be consistent with several levels of the devaluation probability \( \pi \). The following proposition makes
this point more formally, by stating under which conditions the multiplicity of equilibria arises.

**Proposition 1.** The relationship between the fundamental and the devaluation expectation may be characterized as follows.

If $\mu\alpha f(0) < 1$, the devaluation probability $\pi$ is uniquely determined by (and strictly decreasing with) the fundamental $\phi$.

If $\mu\alpha f(0) > 1$, there are two critical values of the fundamental $\phi < \phi^*$ such that:
- if $\phi > \phi^*$ or $\phi < \phi^*$, the devaluation probability $\pi$ is uniquely determined by (and strictly decreasing with) the fundamental $\phi$;
- if $\phi \in (\phi^*, \tilde{\phi})$, the devaluation probability may take three values $\pi_1(\phi) < \pi_2(\phi) < \pi_3(\phi)$.

**Proof.** The proof is based on a graphical representation of Eq. (3). Both sides of the equation are functions of $\pi$, which are represented in Fig. 1. The l.h.s. is the $45^\circ$ line, while the r.h.s. corresponds to the curve $C_\phi$. As Fig. 1 makes clear, this curve may intersect the line in one or several points.

The slope of $C_\phi$ is equal to $\mu\alpha f(d_\pi - \phi)$. The assumptions that we have made about $f(\cdot)$ imply that this slope reaches its maximum at $\pi = \phi/\alpha$, where it is equal to $\mu\alpha f(0)$. We are thus led to distinguish between two cases.

![Fig. 1. Eq. (3).](image-url)
If $\mu\alpha f(0)<1$, the slope of $C_\phi$ is everywhere strictly smaller than 1, so that $\pi$ is uniquely determined by $\phi$, and strictly decreasing with it.

If $\mu\alpha f(0)>1$, the slope of $C_\phi$ is strictly larger than 1 at $\pi=\phi/\alpha$, so that the curve intersects the $45^\circ$ line at three points if it is neither too much to the left nor to the right. This is the case if the fundamental $\phi$ lies between the two critical values $\bar{\phi}$ and $\bar{\phi}$, that are determined as depicted on Fig. 1. The curves $C_\phi$ and $C_{\bar{\phi}}$ must be tangent to the $45^\circ$ line at $(\bar{\pi}, \bar{\pi})$ and $(\bar{\pi}, \bar{\pi})$ respectively. The tangency conditions for $\bar{\phi}$ and $\bar{\pi}$ can be written:

$$
\begin{cases}
\bar{\pi} = \mu F(\alpha \bar{\pi} - \bar{\phi}) \\
1 = \mu\alpha f(\alpha \bar{\pi} - \bar{\phi})
\end{cases}
$$

with $\bar{\phi} < \alpha \bar{\pi}$. Substituting out $\bar{\pi}$ then gives:

$$
\bar{\phi} = \mu\alpha F\left(f^{-1}\left(\frac{1}{\mu\alpha}\right)\right) - f^{-1}\left(\frac{1}{\mu\alpha}\right)
$$

(4)

where $f^{-1}(\cdot) : [0, f(0)] \to \mathbb{R}^+$ denotes the inverse function of $f(\cdot)$ that takes positive values. Noting that $\bar{\phi} > \alpha \bar{\pi}$, similar computations yield:

$$
\bar{\phi} = \mu\alpha F\left(-f^{-1}\left(\frac{1}{\mu\alpha}\right)\right) + f^{-1}\left(\frac{1}{\mu\alpha}\right)
$$

(5)

Q.E.D.

Fig. 2 provides a convenient way to look at the relationship between the fundamentals and devaluation expectations in this model. It represents the locus of the possible combination of fundamentals and devaluation probabilities in the space $(\phi, \pi)$. As the Figure shows, two conditions are necessary for multiple equilibria to arise. The first condition, $\mu\alpha f(0)>1$, relates to the structural parameters of the model. The second condition, $\pi_1, \pi_2 \in (\bar{\phi}, \bar{\phi})$, relates to the time-varying fundamental, so that it can be satisfied at some periods and not at others.

When the fundamental is in a good position $(\phi > \bar{\phi})$, the devaluation probability is uniquely defined and close to zero. Credibility is generally not perfect, insofar as there remains a small probability that a negative shock in the fundamental will force the policymaker off the peg the next period. Symmetrically, when the fundamental is in a bad position $(\phi < \phi)$, the devaluation probability is uniquely defined and close to $\mu$. The policymaker is expected to go off the peg the next period if he is in a soft mood, except in the case of a large positive shock in the fundamental.

When the fundamental lies in the interval $[\bar{\phi}, \bar{\phi}]$, the devaluation probability may take three different values $\pi_1(\phi)$, $\pi_2(\phi)$ and $\pi_3(\phi)$, which makes the fixed peg vulnerable to self-fulfilling speculation. The self-fulfilling character of the devaluation expectations comes from the fact that a high devaluation probability tends to validate itself by decreasing the net benefit of staying in the fixed peg.
exchange rate arrangement the next period. In other terms, the devaluation expectations tend to be self-fulfilling because they make it more costly for the policymaker to maintain the fixed peg.

The discontinuous expansion of the set of equilibria that takes place when the fundamental enters the interval $]\phi, \bar{\phi}[\text{ is known in the theory of non linear dynamics as a bifurcation (Azariadis, 1993, chapter 8). The reason why the multiple equilibria may arise only when the fundamental takes intermediate values can be explained as follows. In this model, market expectations} become self-fulfilling when the expected net benefit of the fixed peg is negative or positive depending on whether devaluation expectations are high or low. This cannot be the case if the fundamental is too high (low), because then the next period benefit is almost always positive (negative) irrespective of market expectations. The sensitivity of the net benefit to the devaluation probability must also be large enough, which explains why the condition $\alpha > 1/\mu f(0)$ is necessary for the existence of multiple equilibria.

In the model like in everyday language, we define a currency crisis as a situation in which the devaluation probability increases abruptly to unusually high levels. As Fig. 2 shows, our model can encompass two competing explanations of how a currency crisis may come about, one based on the fundamentals and the other one based on self-fulfilling speculation. According to the first explanation, a currency crisis may come from a deterioration of the fundamental, i.e., a decrease from a high level of $\phi$ to a low level of $\phi$. In this case, it is clear that the crisis is caused
by the fundamental. The second explanation arises when there are multiple equilibria. In this case, the crisis may be interpreted as a jump from a low devaluation probability \( \pi_1(\phi) \) to a high devaluation probability like \( \pi_2(\phi) \) or \( \pi_3(\phi) \). In some sense, the crisis is also made possible by the fundamental, since it can occur only when the fundamental lies in the appropriate range \((\phi, \tilde{\phi})\), but it is not generated by the fundamental (in particular, it can occur while the fundamental \( \phi \) remains the same). It is generated by the “animal spirits” of the market, which coordinate market participants on high or low devaluation expectations.

The model can accommodate different ways to specify the nature of the “animal spirits”. These spirits may be determined by a publicly observable sunspot variable that coordinate the expectations of the foreign exchange market participants. The sunspot variable may be, for example, the action of a particular type of market participant, like hedge funds, that enjoy the privilege of being observed by the whole market and may in this way provide the focal point for market expectations (see, e.g., Goldstein et al., 1993). It may also indicate the arrival of good and bad “news” abruptly changing the mood of the market. It is important to note that this sunspot variable does not need to be related to the fundamentals since it is sufficient for each individual market participant to see that the others are speculating against the currency to join them, irrespective of the reason why they are doing so. From this point of view, the model can be viewed as a simple structure allowing us to understand why speculating against the currency may be contagious even when market participants are perfectly rational.

3. Estimation

Estimation of the model can allow us to assess whether self-fulfilling speculation is at work in specific episodes of speculation. One simply needs to determine whether: (i) the estimated parameters satisfy the condition \( \mu > 1 \); (ii) the estimated fundamental lies in the interval \((\phi, \tilde{\phi})\) and (iii) the devaluation expectations exhibit evidence of jumps across different states. We present in this section an estimation procedure based on the Maximum Likelihood method, that is closely inspired by Dagsvik and Jovanovic (1994).\(^9\)

We estimate the model of the previous section in the following form:

\[
\pi_t = \hat{\pi}_t + \eta_t
\]

\[
\hat{\pi}_t = \mu F(\hat{\pi}_t - \phi_t)
\]

\(^9\)Dagsvik and Jovanovic scrutinize an empirical question which is very different from that studied in this paper: they attempt to determine whether there is evidence of multiple equilibria during the 1929 crisis in the United States (and obtain a negative answer).
\[
\phi_t = \gamma' x_t 
\]  

(8)

The first equation states that the devaluation probability observed at time \( t \) is equal to the value predicted by the model, \( \hat{\pi}_t \), plus a prediction error \( \eta_t \), which is assumed to be i.i.d. normal with variance \( \sigma^2_{\eta} \). The second equation is simply Eq. (3) in which \( F(\cdot) \) is specified to be the cumulative distribution function of a normal distribution with variance \( \sigma^2 \) and \( \alpha \) normalized to 1 (otherwise, the parameters are not identified because multiplying \( \alpha, \sigma \) and \( \gamma \) by the same factor does not change \( \hat{\pi} \)). The third equation is a linear specification of the fundamental, where \( x \) is a vector including relevant macroeconomic variables and a constant, and \( \gamma \) is a vector of coefficients.

In order to complete the model, we need to specify how the "animal spirits" behave, i.e., to define the selection mechanism of the state of the economy when there are multiple equilibria. For this purpose, we define the state variable \( s_t \) as \( s_t = i \) if the economy lies on branch \( i \) of the curve depicted in Fig. 2 at date \( t \) \((i = 1, 2, 3)\). Like Dagsvik and Jovanovic (1994), we assume that the selection mechanism follows a stochastic Markov process which is independent from the fundamental. As Jovanovic (1989) has shown, assuming that the sunspot variable is independent from the fundamental is necessary to distinguish empirically the sunspot process from the fundamental process. Taking a Markov state transition process is a specification which is both simple and general enough for our purpose. We assume that the state selection process is characterized by the \( 3 \times 3 \) Markov matrix \( \Theta = (\theta(i,j))_{1 \leq i,j \leq 3} \), where the coefficients \( \theta(i,j) \) are the probabilities of transition from state \( i \) to state \( j \) when the fundamental lies in the range \( (\phi, \bar{\phi}) \).

The state 2 equilibrium has some undesirable properties, which makes it a less plausible candidate than state 1 and state 3 equilibria. First, it tends to become dynamically unstable when foreign exchange market participants form their expectations in an adaptive way.\(^1\) Second, it makes the relationship between the fundamental and the devaluation expectations rather counterintuitive, since the devaluation probability increases with the fundamental in state 2. For these reasons, we constrain the economy to be in state 1 or 3, i.e., we adopt the restriction:

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

In order to simplify the notation, we introduce the variable \( z \) defined by:

\(^1\)For example, consider the case where each agent forms his expectation assuming that all other agents keep the same expectations as in the previous period. Equation (3) is then replaced by \( \pi_t = \mu F(\alpha \pi_{t-1} - \phi) \), which yields two stable equilibria (corresponding to states 1 and 3) and one unstable equilibrium, corresponding to state 2.
\[ z = \frac{\mu}{\sigma \sqrt{2\Pi}} \]

(where \( \Pi \) denotes the constant 3.141...) so that the condition \( \mu \sigma f(0) > 1 \) may be rewritten:

\[ z > 1 \]

The purpose of the estimation is to estimate the exogenous parameters of the model \( \gamma, \Theta, z, \mu \) as well as the sequence of states \((s_t)_{t=1}^T\), from the series of data \((x_t, \gamma)_{t=1}^T\), and \((\pi_t)_{t=1}^T\),\(^{11}\) The estimation is implemented using the Maximum Likelihood method. As the state transition process is independent from the fundamental process, we may write the likelihood function as the product of the likelihood function of the model prediction error and that of the state:

\[ L = L_\eta L_s \]

where:

\[ L_\eta = \frac{1}{(\sigma_\eta \sqrt{2\Pi})^T} \exp \left( -\frac{1}{2\sigma_\eta^2} \sum_{i=1}^{T} \eta_i^2 \right) \]  \hspace{1cm} (10)

\[ L_s = \prod_{t \in \Delta} \theta(s_{t-1}, s_t) \]  \hspace{1cm} (11)

and \( \Delta \) is the set of dates at which the transitions across states are possible, i.e. \( \Delta \equiv \{ t, \phi, \psi \in (\phi, \psi) \} \). We assume that when the fundamental enters the interval at time \( t \) (i.e. \( t-1 \in \Delta \) and \( t \in \Delta \)) the probability of state \( s_t \) is \( \theta(s_{t-1}, s_t) \).

Maximizing over \( \sigma_\eta \) and leaving aside an unimportant constant, the logarithm of the likelihood can be written:

\[ \log L = -\frac{T}{2} \log \left( \sum_{t=1}^{T} \eta_t^2 \right) + \sum_{t \in \Delta} \log \theta(s_{t-1}, s_t) \]

Maximizing this function over the states \((s_t)_{t=1}^T\) is difficult because this is a discrete maximization problem. A convenient simplification is to identify the state so as to minimize the absolute value of the prediction error \( \eta_t \) at each period \( t \). This simplification may bias the estimation against the existence of multiple equilibria, since it tends to underestimate the likelihood function when there are

\(^{11}\)The measurement of the devaluation probability raises specific problems, which have been studied in particular by Bertola and Svensson (1993); Svensson (1993); Rose and Svensson (1994) in the context of the EMS. More discussion of this point may be found in the following section. In the present section, which is dedicated to the presentation of the test in abstracto, we leave aside this measurement problem and simply take the series \((\pi_t)_{t=1}^T\) as given.
multiple equilibria, but it also makes it possible to identify the sequence of states $(s_i)_{i=1}^T$ given $\gamma$, $\mu$, $z$ and the data.

Once the states are identified, it is not difficult to estimate the state transition process. Given the estimated sequence of states, one must maximize:

$$\log L_x = \sum_{i \in \Delta} \log \theta(s_{i-1}, s_i)$$  \hspace{1cm} (12)

over $(\theta(i,j))_{(i,j) \in \{1,3\}^2}$ under the Markov constraints $\sum_{j=1}^3 \theta(i,j) = 1$ ($i = 1,3$). Denoting by $n(i,j)$ the number of times $t \in \Delta$ at which a transition from state $i$ to state $j$ takes place, we may rewrite $\log L_x$ as:

$$\log L_x = \sum_{(i,j) \in \{1,3\}^2} n(i,j) \log \theta(i,j)$$  \hspace{1cm} (13)

Maximizing (13) under the constraints then yields the estimates:

$$\hat{\theta}(i,j) = \frac{n(i,j)}{n(i)}$$  \hspace{1cm} (14)

where $n(i) = n(i,1) + n(i,3)$ is assumed to be different from zero. Formula (14) states that the estimated probability of transition from state $i$ to state $j$ is equal to the number of times the economy has jumped from state $i$ to state $j$ divided by the number of times the economy was in state $i$ and could jump.

Once the maximization over the states and the state transition process has been concentrated, it remains to maximize $\log L$ over $z$, $\mu$, and $\gamma$. This can be done using the algorithms available in standard econometric software.\textsuperscript{12} In order to test for the presence of self-fulfilling speculation, one must determine whether $z > 1$ and $\phi_1(\theta, \bar{\phi})$. One can test the null hypothesis $H_0$: $z \leq 1$ by applying the Likelihood Ratio Test. Let us define the log likelihood ratio as:

$$LR = 2 \log \left( \frac{L^*}{L^*_z} \right)$$  \hspace{1cm} (15)

where $L^*$ is the maximum value of the likelihood function $L$, and $L^*_z$ is the maximum of $L$ under the constraint $z = 1$. The Likelihood Ratio test says that one may asymptotically reject the null hypothesis at the 1% level if $LR$ is larger than $LR^* = 6.635$.\textsuperscript{13}

\textsuperscript{12}One should note that because the model exhibits bifurcation, the likelihood function is not continuous, which makes its maximization difficult. In particular, it is necessary to use algorithms that do not rely too sensitively on the numerical gradient of the likelihood function, like the simplex algorithm.

\textsuperscript{13}The critical value $LR^*$ is defined by $\Pr \{ \chi^2_1 > LR^* \} = 1\%$ (see Harvey, 1990, p.165).

The French franc suffered several speculative attacks in 1992 and 1993, and could only stay in the Exchange Rate Mechanism of the EMS at the cost of a considerable widening of the fluctuation margins at the beginning of August 1993. The purpose of this section is to evaluate how the model of the previous section helps us to understand the relationship between the fundamentals and the devaluation expectations of the French franc in 1992–3. The experience of the French franc is especially interesting for our purpose because the franc, unlike the sterling or the lira, did not succumb to the first speculative attack of September 1992 and thus exhibits several episodes of speculation that were not followed by a change of regime. We first discuss the data, before we come to the results of the test and their interpretation.

We use monthly data from January 1991 to July 1993. The macroeconomic variables constituting the fundamentals are the real exchange rate, the trade balance GDP ratio, and the unemployment rate. The fluctuations of the real exchange rate have been moderate, and did not exhibit any clear tendency during the sample period. These fluctuations essentially reflect the variations of the franc with respect to the U.S. dollar. The real competitiveness of France relatively to Germany, on the other hand, was roughly constant during the sample period. As Fig. 3b makes clear, the trade balance has showed a clear tendency to improve, and was markedly positive at the end of the sample period. We did not include variables related to fiscal policy, because of the lack of reliability of these data at the monthly frequency, and because they were probably not important determinants of the French franc credibility: the French budget deficit remained among the lowest in Europe, and the ratio of public debt to GDP compared favourably with most other European countries. The only important weakness of the French economy was a high and rising unemployment rate (see Fig. 3c).

Fig. 3d shows the devaluation probability of the French franc with respect to the German mark. The speculative episodes to which the French franc was submitted in September 1992, the first quarter of 1993, and July 1993 clearly appear on the figure. The measure of the devaluation probability is based on the drift adjustment method developed by Svensson and other authors in several papers (Bertola and Svensson, 1993; Svensson, 1993; Rose and Svensson, 1994). These authors argue that the interest rate differential is a very imperfect measure of the expected devaluation in target zones, because it mixes the expected

\[14\text{Source: IMF. The computation of the real exchange rate is based on the domestic production cost (variable rervx in the IMF statistics). An increase in this index corresponds to a real appreciation of the domestic currency. We have used the logarithms of the real exchange rate and the unemployment rate in the estimation.}\]

\[15\text{For a clear description of the development of the French franc crisis, see Moutot (1994).}\]
depreciation inside the band with the expected realignment of the central parity. They propose a way to tackle this problem, which consists in estimating the stochastic process of the exchange rate inside the band, and remove from the
interest rate differential that component which is due to the intra-band fluctuations. As devaluation expectations can be very volatile and short-lived during a crisis, we use monthly averages of daily estimates of the drift-adjusted devaluation expecta-
Table 1

<table>
<thead>
<tr>
<th>Term</th>
<th>Linear regression</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \gamma )</td>
<td>-3.656</td>
<td>0.0831</td>
</tr>
<tr>
<td>( \gamma_u )</td>
<td>(-41.671 \times 10^{-3})</td>
<td>(-0.650 \times 10^{-3})</td>
</tr>
<tr>
<td></td>
<td>(0.670)</td>
<td>(0.071)</td>
</tr>
<tr>
<td>( \gamma_l )</td>
<td>0.826</td>
<td>-6.630 \times 10^{-3}</td>
</tr>
<tr>
<td></td>
<td>(0.034)</td>
<td>(0.035)</td>
</tr>
<tr>
<td>( \gamma_b )</td>
<td>4.983 \times 10^{-3}</td>
<td>3.059 \times 10^{-5}</td>
</tr>
<tr>
<td></td>
<td>(0.589)</td>
<td>(0.456)</td>
</tr>
<tr>
<td>( \mu )</td>
<td></td>
<td>0.1015</td>
</tr>
<tr>
<td>( z )</td>
<td></td>
<td>1.0565</td>
</tr>
<tr>
<td>( \log L^* )</td>
<td>124.84</td>
<td>137.66</td>
</tr>
<tr>
<td>( \log L_{t-1}^* )</td>
<td>124.67</td>
<td></td>
</tr>
</tbody>
</table>

The \( P \)-values are indicated in parentheses.

The series of devaluation probability \(( \pi_t^T \)\) is then derived under the assumption that the expected size of the devaluation was 5%.

The results of the estimation are given in Table 1. For the sake of comparison, we also included the results of a linear regression of the devaluation probability on the macroeconomic variables. The linear regression can be viewed as the estimation of the model (6)-(7)-(8) in which Eq. (7) is replaced by the identity \( \hat{\pi}_t = \hat{\phi}_t \), so that the likelihoods given in columns 1 and 2 of Table 1 are directly comparable. As the comparison of the likelihoods shows, the model performs significantly better than the linear regression and what makes the model outperform the linear regression is the possibility of bifurcation and multiple equilibria. When the model is estimated under a restriction that rules out these phenomena \((z = 1)\), the likelihood is not significantly different from that of a linear regression. One can see that \( z \) is significantly larger than 1 by noting that the Likelihood Ratio, equal to \( LR = 2(\log L^* - \log L_{z=1}^*) = 26 \), is well above the critical value \( LR^* = 6.6 \) that would allow us to reject the null hypothesis \( z = 1 \) at the 1% level.

The model also improves upon the linear regression in the estimation of coefficients \( \gamma \). The expected signs of the coefficients are \( \gamma_u > 0, \gamma_l > 0 \) and \( \gamma_b < 0 \) in the linear regression, since an increase in the unemployment rate or a deterioration of French real competitiveness or trade balance are expected to increase devaluation expectations. One observes in the first column of Table 1 that the only macroeconomic variable that is significant is the real exchange rate, while the coefficients for unemployment and the trade balance have the wrong signs and are not significantly different from zero. The expected signs of the coefficients in the second column of Table 1 are \( \gamma_u < 0, \gamma_l < 0 \) and \( \gamma_b > 0 \), since the fundamental \( \phi \) should be decreasing with the unemployment rate and the real exchange rate and increasing with the trade balance. It turns out that the coefficients have the
expected signs and two of them (those of unemployment and the real exchange rate) are statistically significant at the 10% level.\textsuperscript{16}

Fig. 4 shows the estimated fundamental, $\hat{\phi}$, together with the threshold level $\phi$. One can divide the period into two subperiods separated by a bifurcation that occurred in August 1992. Before August 1992, the fundamental $\phi$ is high enough to prevent the emergence of self-fulfilling speculation. After August 1992, the fundamental enters the zone of multiplicity and self-fulfilling speculation could arise. The evolution of the fundamental was essentially determined by two variables, the real exchange rate and the unemployment rate. The large deterioration of the fundamental that led the economy into the zone of multiplicity is due to the fall of the dollar between the Summer of 1991 and that of 1992. The dollar strengthened in the last year of the sample period, but this effect was counterbalanced by the rise in the unemployment rate, which maintained the fundamental in the zone of multiplicity until the end of the sample period.

![Graph](image)

**Fig. 4.** The fundamental.

\textsuperscript{16}The marginal significance levels (or P-values) indicated in column 2 of Table 1 are asymptotic estimates resulting from the Likelihood Ratio.
Table 2

Matrix \( \Theta \)

\[
\begin{pmatrix}
0.4 & 0 & 0.6 \\
0 & 1 & 0 \\
0.33 & 0 & 0.67
\end{pmatrix}
\]

The importance of the real exchange rate in the fundamental may seem surprising in view of the analyses that argue that the French franc was not overvalued in 1992–3 (Eichengreen and Wyplosz, 1993; Svensson, 1994). It should be noted, however, that while these analyses focus on the real competitiveness of the franc with respect to the mark, it is the exchange rate relative to non-EMS currencies—especially the dollar—that seems to matter here. There are several channels through which fluctuations of the dollar can influence the stability of the EMS, the most convincing ones being related less to real competitiveness than to the portfolio allocation of international investors. As Giavazzi and Giovannini (1986) have documented, when the dollar is weak investors reallocate their portfolio toward German mark denominated assets, which tends to generate tensions in the EMS. Our analysis suggests that this effect may have been more important in the French franc crisis than is usually acknowledged.

As the estimate of the state transition matrix given in Table 2 shows, self-fulfilling speculation was very likely to occur once the fundamental had entered the zone of multiplicity: the economy was more likely to be in a state of crisis (state 3) than not. The role of self-fulfilling speculation is made apparent in Fig. 5, which compares the realized devaluation probability \( \pi \), with the value \( \hat{\pi} \) predicted by the model and the estimate resulting from a linear regression. As the jumps in variable \( \hat{\pi} \) show, self-fulfilling animal spirits allow the model to capture the well-identified episodes of acute speculation which took place in 1992 and 1993. During these episodes, the interest rate premium imposed by self-fulfilling speculation could reach 5%. The model does not explain satisfactorily the month-to-month fluctuations in the devaluation expectations outside the episodes of crisis, but the linear regression is not very successful in this respect either.

5. Concluding comments

We have presented a model which, though very stylised, encompasses and articulates in a new way the main competing hypotheses about the origin of speculation in currency crises. This model allows us to view self-fulfilling speculation as a phenomenon resulting from a bifurcation in the fundamental economic variables. Indeed, the notion of bifurcation seems quite promising in thinking about the relationship between fundamentals and speculation in general,
since it would arise in any model in which the possibility of market spirits would depend on the configuration of the fundamentals.

We have also illustrated the potential empirical benefit of this approach by showing that the model does a significantly better job of tracking the devaluation expectations of the French franc in 1992–3 than a linear regression. It would be interesting to estimate our model in other episodes of currency crisis, like those related to other EMS currencies or the Mexican peso. On the one hand, one should probably not expect to obtain markedly different results about the existence of self-fulfilling speculation than those obtained in the case of the French franc. The reason is that for those currencies like for the French franc, the devaluation expectations appeared too suddenly and unexpectedly to be satisfactorily explained only by the macroeconomic fundamentals. One may conjecture that the difference between the French franc and other currencies, if it exists, probably lies more in the nature of the determining fundamentals than in the presence of animal spirits. On the other hand, the fact that some currencies devalued following the first strike of speculation may make the evidence of self-fulfilling speculation statistically less significant.

Another natural extension would be to enlarge the set of fundamentals that we
consider in the estimation of the model. In a recent paper, Krugman (1996) argues that in order to explain the excessive volatility of devaluation expectations one should take into account the impact of political variables like elections or reports of disagreement between policymakers. While nothing in our model would prevent us from adding dummy variables associated with political events in the definition of the fundamental, taking into account political fundamentals raises several delicate issues. First, because political news arrives much more often than information about the state of the economy, it would be necessary to consider higher frequency (probably daily) data. Second, in order to avoid the trap of explaining all the observations in terms of ad hoc political dummy variables, one would need to adopt a definition of the political fundamentals restricted to events that seem objectively relevant for the policymakers’ decisions. Third, while the absence of correlation between political news and speculation would bring support to the hypothesis of self-fulfilling speculation, the presence of such a correlation would be difficult to interpret: would it mean that political variables are part of the fundamentals or that they play the role of sunspot variable coordinating the expectations of speculators? In spite of these difficulties, integrating political variables into the analysis should figure high on the research agenda of currency crises.

Acknowledgments

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References


17The problems raised by the integration of political fundamentals in the analysis are discussed at more length in Jeanne and Masson (1996).


