

Currency Crises, Sunspots and Exchange-Rate Overshooting

Julian Inchauspe*

This paper provides a macroeconomic framework for theoretical and empirical analysis of the role of sunspots and shock-dependent expectations in currency crises. The model distinguishes between macroeconomic fundamentals and shock expectations as cause of currency crises. It is assumed that good prices are sticky so that the economy responds to information through the exchange rate or, when it is fixed or managed, through the interest rate. I argue that, under certain conditions, pessimistic expectations can be strong enough to self-validate and bring about crises.

Fields of Research: Economic Policy, International Economics, Foreign Exchange, Macroeconomics.

1. Introduction

Motivated by the Asian crisis in 1997-8 and the *European Monetary System* (EMS) crash in 1992-3, in this paper we present a general model and then, as a way of example, we analyse data from the South Korean crisis of 1997-8. The novel aspect of this paper is the combination of elements from models of self-fulfilling currency crises, exchange-rate overshooting models and empirical analysis with Markov-switching time-series techniques. Although this work focuses on the crises of the 1990s, many of the features of these crises might also be relevant to an understanding of some of the most recent crisis episodes.

Interestingly, many of the crises in the 1990s share common macroeconomic characteristics. First, these economies had used fixed or tightly-managed exchange rates and undergone capital-account liberalizations prior to the crises. Second, it seems to be the case that there was a preceding high interest rate that made the economies of these countries unviable. Third, after devaluation, their nominal exchange rate typically '*overshot*' over some period after which it returned to a more appreciated value. These issues will be investigated, explained and contrasted with data in this paper in an appropriate *macroeconomic* model in which expectations,

*Department of Economics, Macquarie University, NSW 2109, Australia.

E-mail: jinchaus@efs.mq.edu.au

shocks and sunspot equilibria play a crucial explanatory role. Given this brief introduction, the balance of the paper is organised as follows. Section 2 presents a review of related literature. Section 3 introduces the main model. In Section 4 we introduce an empirical illustration by applying Markov-switching time-series econometric techniques to the South Korean crisis. Section 5 discusses how the model could be modified to consider the *contagion* effects and links in the 1997 Asian crisis. In Section 6 we present concluding remarks.

2. Literature Review

One highly-discussed concern about recent currency crises has been the extent to which they have been provoked by macroeconomic ‘fundamentals’ or by self-fulfilling pessimistic expectations [Masson, 2007; Jeanne, 2000]. First-generation models of currency crises, as they are known as in the literature, suggest that a speculative attack on a currency arises as a consequence of a steady deterioration in macroeconomic fundamentals, typically because the exchange rate was misaligned or macroeconomic policies were time-inconsistent [Krugman, 1979; Flood & Garber, 1994]. However, in the 1997-8 Asian crisis and the 1992-3 EMS one, there was no obvious steady deterioration in macroeconomic fundamentals that would have suggested that an exchange rate adjustment was needed. Responding to this, second-generation models of currency crises suggest that crises can be caused by self-fulfilling expectations [Obstfeld, 1996; Jeanne, 1997]. This paper introduces a macroeconomic framework that allows for evaluating whether crises are the result of inadequate macroeconomic policies which result in troublesome macroeconomic fundamentals or whether they are the result of some kind of expectation shock. Having explained that, it must be said that the model in this paper focuses on macroeconomic aspects of crises that can be matched to data. The model does not go into details about its micro-foundations, the financial market failures that may have allowed for (and exacerbated) crises or other important features analysed in third-generation models. The use of a general macroeconomic framework which could be matched to data has rarely been seen in the literature. A general equilibrium macroeconomic analysis of the Asian crisis (which is not taken to data) is given by Aghion, Bacchetta & Banerjee, 2001.

A justification for the use of Markov-switching techniques to analyse the role of multiple equilibria can be found in Martinez-Peria, 1997. This work sets a precedent for the use of multivariate econometric techniques in the EMS crisis context. Many researchers have used Markov-switching techniques to study multiple equilibria (see Jeanne, 2000, for a review). The design of an appropriate macroeconomic framework of analysis involves some crucial decisions about its assumptions. The first consideration is that most countries which suffered currency crises had used fixed or tightly-managed exchange rate arrangements prior to its occurrence. A second characteristic to be considered is that these countries had liberalised their capital accounts, though still with imperfect substitution between local and foreign assets. A convenient framework to work on is the Dornbusch-Mudell-Flemming model as introduced in Wickens, 2008, and discussed in Rogoff, 2002, and Obstfeld & Rogoff, 1996. A key assumption in the Dornbusch-Mudell-Flemming exchange-

Inchauspe

rate overshooting model is that prices are flexible but sticky, so that exchange rate reacts with immediate shifts to forward-looking expectations. We use this framework to incorporate sunspot equilibria.

3. The Model

3.1. Assumptions

The model represents a small economy with full-capital mobility. Initially we assume that the exchange rate is flexible but this assumption is modified later. As in the Dornbusch-Mundell-Flemming model, prices are flexible but sticky, so they adjust at a slower rate than exchange and interest rates which carry all the price adjustment of the economy. The model is represented by the following set of log-linearised equations:

$$\begin{cases} y_t^d = \alpha(s_t + p_t^* - p_t) - \beta l_t + \gamma y_t - g_t + u_t, & (1) \\ \Delta p_t = \theta(y_t^d - y_t) + v_t, & (2) \\ m_t = p_t + y_t - \lambda l_t + w_t, & (3) \\ i_t = i_t^* + E_t \Delta s_{t+1}, & (4) \end{cases}$$

Where all the coefficients are defined $\alpha, \beta, \gamma, \theta, \lambda > 0$, and u_t , v_t and w_t are assumed to be zero-mean *i.i.d.* shocks. Following the tradition of the literature and the focus on the medium run demand-side effects, it is assumed that output supply is exogenously given, whereas aggregate demand y_t^d is driven according to equation (1), by real exchange rate $\alpha(s_t + p_t^* - p_t)$, investment $-\beta l_t$, consumption γy_t , and government spending g_t . In the medium run, prices stickiness allows for the Phillips curve relation given in equation (2) between excess demand from potential output $\theta(y_t^d - y_t)$ and output prices Δp_t . Money market equilibrium is then defined by logarithmic equation (3), where m_t represents money supply and l_t represents interest rate. Finally equation (4) represents the *uncover interest rate* parity condition: domestic interest rate i_t equals foreign interest rate i_t^* plus expected exchange rate depreciation (appreciation) $E_t \Delta s_{t+1}$. The nominal exchange rate is defined in terms of domestic currency per unit of foreign currency, so that an increase in s_t represents a depreciation.

Inchauspe

3.2. Equilibrium and Dynamics

By combining Equations (1), (2), (3) and (4), it is possible to obtain the following reduced-form solutions:

$$\begin{cases} p_t = \mu p_{t-1} + \phi s_t + a_t, & (5) \end{cases}$$

$$\begin{cases} s_t = E_t s_{t+1} - \frac{1}{\lambda} p_t + b_t, & (6) \end{cases}$$

Where,

$$\mu = \left[1 + \theta \left(\alpha + \left(\frac{\beta}{\lambda} \right) \right) \right]^{-1}, \quad \phi = \mu \alpha \theta,$$

$$a_t = \mu \theta \left(\gamma - 1 - \frac{\beta}{\lambda} \right) y_t + \frac{\mu \beta \theta}{\lambda} m_t + \mu \theta g_t + \mu \alpha \theta p_t^* + \mu \theta u_t - \frac{\mu \beta \theta}{\lambda} w_t + \mu v_t, \quad (7)$$

$$b_t = -\frac{1}{\lambda} y_t + \frac{1}{\lambda} m_t + t_t^* - \frac{1}{\lambda} w_t, \quad (8)$$

As it is characteristic in Dornbusch-Mundell-Flemming model, equation (5) is backward-looking whereas (6) is forward looking. To find the steady states levels of price and exchange rate, we apply the backward/forward lag operator L which defines $x_{t-t} = L^t x_t$ and $E_t x_{t+t} = L^{-t} x_t$ (this assumption implying perfect foresight is revised later). This allows us to write:

$$[\lambda - (\mu\lambda + \lambda + \phi)L + \mu\lambda L^2] L^{-1} s_t = x_t, \quad (9)$$

Where $x_t = a_t - \lambda(1 - \mu L)b_t$ is a stationary⁽ⁱ⁾ *fundamental variable* that represents all the fundamental variables of the economy contained in a_t and b_t . Equation (9) can also be written as $\mu\lambda f(L)L^{-1} s_t = x_t$ implying the following characteristic function:

$$f(L) = \frac{1}{\mu} - \left(1 + \frac{1}{\mu} + \frac{\phi}{\mu\lambda} \right) L + L^2 = 0, \quad (10)$$

As $f(1) = -\left(\frac{\phi}{\mu\lambda}\right) < 0$, equation (10) has a *saddlepath* solution. Denoting the roots of (10) with $\eta_1 > 1$ and $\eta_2 < 1$, equation (10) can be re-written as,

$$f(L) = (L - \eta_1)(L - \eta_2) = -\eta_1 \left(1 - \frac{1}{\eta_1} \right) (1 - \eta_2 L^{-1}),$$

Inchauspe

This yields the following exchange-rate solution:

$$s_t = \eta_1^{-1} s_{t-1} - \frac{1}{\mu\lambda(\eta_1 - 1)} \sum_{i=0}^{\infty} \eta_1^i E_t x_{t+i} \quad (11)$$

which can be written in the following adjustment form:

$$\Delta s_t = \left(1 - \frac{1}{\eta_1}\right) (\bar{s}_t - s_{t-1}) \quad , \quad \bar{s}_t = -\frac{1}{\mu\lambda(\eta_1 - 1)} \sum_{i=0}^{\infty} \eta_1^i E_t x_{t+i}$$

Where \bar{s}_t is the steady-state solution. Three things have to be noticed about the exchange-rate solution. First, its path involves backward-looking and forward-looking components. Second, steady-state exchange rate depends on the (expected value) of macroeconomic fundamentals embodied in x_t . Third, a shock in the fundamental variable implies an immediate shift in \bar{s}_t and a smooth adjust of nominal exchange rate over time. Finally, the price path solution can be obtained after replacing \bar{s}_t in (5):

$$p_t = \left(\mu - \frac{1}{\eta_1}\right) p_{t-1} - \frac{\mu}{\eta_1} p_{t-2} - \frac{\phi}{\mu\lambda\eta_1} \sum_{i=0}^{\infty} \eta_1^i E_t x_{t+i} + \alpha_t - \frac{1}{\eta_1} \alpha_{t-1} \quad (12)$$

Equation (12) exhibits price rigidities. It is well-known that because the adjustment of prices is slower than the nominal exchange rate adjustment, models such as this one predict a nominal exchange-rate *overshooting* [Dornbusch, 1976]. So far, we have analysed what would happen if the exchange rate was flexible. Next section extends the analysis to fixed exchange-rate schemes.

3.3. Fixed Exchange Rate Analysis

Unless further restrictions such as a monetary rule or an exchange rate policy are imposed, the solution of the model characterised by equations (11) and (12) is *indeterminate*, in the sense that multiple levels of prices and exchange rate satisfy these equations. Moreover, even though long-run *real* exchange rate and output are fixed, the short-run adjustment may have different real implications for these variables.

A monetary or exchange-rate policy rule is a constraint on equations (3) and (4) that can take various forms. Roughly speaking, central banks have only one important and powerful tool (open market operations) to control inflation, interest rate and exchange rate. Only one of these three variables can be targeted at a time. We have interest in analysing *fixed exchange rate policies*. Fixed or tightly controlled exchange rates were characteristic of most currency crises.

A fixed exchange rate scheme implies $\Delta s_t = 0$ but does *not* imply by any means that no devaluation (appreciation) should be expected. There is no reason why the term $E_t \Delta s_{t+1}$ in equation (4) should be zero. If a devaluation is expected, the interest rate increases in (4), and affects y_t^d and m_t according to (1) and (3). This produces a shift in the fundamental term α_t and a consequent adjustment through prices

Inchausepe

according to equation (5). Prices will continue to adjust until the economy eventually reaches a new equilibrium where $\Delta s_{t+1} = E_t \Delta s_{t+1} = 0$. However, the adjustment process through prices could be lengthy and bring undesired effects on real variables in the medium run. If the overall adjustment process is too damaging for the economy, the policymaker might want to choose to quit the fixed exchange rate arrangement.

The last observation implies two important aspects of currency crises. The first one is that if policymakers decide to devalue is because the net benefit of devaluing is actually higher than the net benefit of keeping the peg. Theoretically, a devaluation decision implies the comparisons of these two net benefit functions. These functions should incorporate the cost of adjustment of macroeconomic variables. Moreover, the difference between the net benefits of flexible and fixed exchange rates should be increasing with the exchange rate misalignment (i.e., the interest rate). A second observation is that if a shock is expected in either u_t , v_t and w_t , this would cause a shift in $E_t \Delta s_{t+1}$ which could outweigh the way net benefits of the peg and flexible exchange rate compare to each other. This type of *sunspot equilibria* incorporate the possibility of self-fulfilling currency crises, in the sense that expectatives about devaluation could self-validate through high interest rates in the money market. An example of this based on unemployment is given by Obstfeld, 1996. For a convenient extension of the model, we follow the approach laid down by Jeanne, 1997. Let B_{t+1} denote the difference between the net benefits of fixed and flexible exchange rate regimes. In period $t+1$, the currency peg is abandoned if, and only if, $B_{t+1} < 0$ and survives otherwise:

$$B_{t+1} = \chi_{t+1} - \tau(l_t - l_t^*) \chi_t, \quad (13)$$

The policymaker evaluates equation (13) at period $t+1$ *after* the private sector expectations about devaluation are formed in period t . The r.h.s. of (13) is decomposed in two terms. The term χ_{t+1} is defined as $\chi_{t+1} = x_{t+1} + \rho(R_t, \xi_t) = a_{t+1} - \lambda(1 - \mu L)b_{t+1} + \rho(R_t, \xi_t)$ and includes *all* the relevant macroeconomic for devaluation decision problem. χ_{t+1} includes not only the fundamental variable x_{t+1} of the model but also other fundamentals $\rho(R_t, \xi_t)$ where R_t represent the level of international reserves and ξ_t represents other exogenous factors affecting the solvency and liquidity of the country such as maturity and currency composition of external debt and public debt. It is assumed that $\rho'(R_t) < 0$ and $\rho'(\xi_t) > 0$. Note that χ_{t+1} excludes the *interest rate*, which is now determined endogenously according the fixing exchange-rate rule (13) along with prices through (5) and exchange rate (assumed fixed). A long-run equilibrium is characterised by either $(p_{L,t}, x_t)$ when the exchange rate is fixed, and $(p_{L,t}, s_t, x_t)$ when flexible.

The second term of the r.h.s. of (13), i.e. $\tau(l_t - l_t^*) \chi_t$, is the expected rate of devaluation as defined by (4), using an up-to-date complete set of information $\{x_t, J_t\}$. The interest rate differential re-scaled by $\tau > 0$ can be used as a proxy of expected probability of devaluation, i.e. $\tau(l_t - l_t^*) \chi_t \in [0, 1]$. If agents in the economy have rational expectations, they must correctly assess the risk that a fundamental variable shock could bring about devaluation. A formal approach to this

Inchauspe

problem is as follows. Let us assume that the fundamental variable x_t is a stationary process that can be described by an autoregression of order N :

$$x_t = A_0 + \sum_{i=1}^N A_i x_{t-i} + \varepsilon_t, \quad (14)$$

Where it is assumed that $\varepsilon_t \sim n(\mu, \sigma^2)$ is a function of the shocks u_t , v_t and w_t of the economy⁽ⁱⁱⁱ⁾. Using this definition and denoting $f(\cdot)$ and $F(\cdot)$ the density and c.d.f. of the distribution of ε_t (and x_t), the probability of that the policymaker will devalue in period $t+1$ is given by,

$$\begin{aligned} \psi \Pr[B_{t+1} < 0] &= \psi \Pr[s_{t+1} < \tau(l_t - l_t^* | x_t, \mathcal{I}_t) - x_{t+1}] \\ &= \psi F \left[\tau(l_t - l_t^* | x_t, \mathcal{I}_t) - \left(A_0 + \sum_{i=1}^N A_i x_{t-i+1} \right) \right], \end{aligned} \quad (15)$$

In equation (15), it should be noticed that the probability of the policymaker devaluing increases as the fundamental variable x_{t-i} deteriorate. The constant $\psi \in (0,1)$ gives a measure of the policymaker pegging toughness: a hard pegger is less likely to devalue for any level of B_{t+1} .

The policy-maker reaction function (15) is known and incorporated by agents in their information set \mathcal{I}_t . Therefore, under *rational expectations* the probability of devaluation of the private sector, i.e. $\tau(l_t - l_t^* | x_t, \mathcal{I}_t)$ have to be equal to the actual probability that the policymaker devalues the currency given by (15). This condition has to be satisfied at all times. Formally, a rational-expectation equilibrium is a fixed-point in the reciprocal mapping between the private sector beliefs and policymaker's actions at all times:

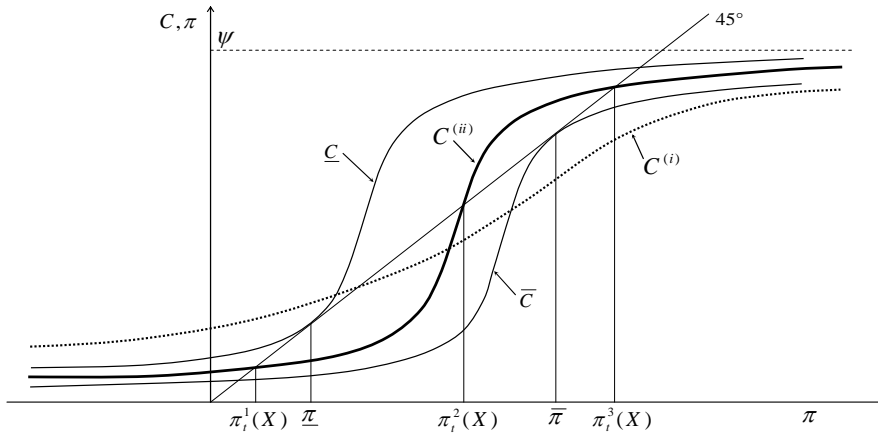
$$\tau(l_t - l_t^* | x_t, \mathcal{I}_t) = \psi F \left[\tau(l_t - l_t^* | x_t, \mathcal{I}_t) - \left(A_0 + \sum_{i=1}^N A_i x_{t-i+1} \right) \right], \quad (16)$$

As both the r.h.s. and the l.h.s. of equation (16) are increasing in $\tau(l_t - l_t^* | x_t, \mathcal{I}_t)$, but at different rate, equation (16) may admit multiple solutions. It is of special interest to analyse under which conditions multiple equilibria may arise. For the sake of simplicity, we will now let π and $C(\pi)$ denote the l.h.s. and r.h.s. of (16) respectively. Using the properties of the c.d.f. $F(\cdot)$, $C(\pi)$ is plotted in Figure 1. The slope of $C(\pi)$ is

Inchauspe

given by: $\frac{\partial C}{\partial \pi} = \psi \tau f' [d(l_t - l_t^e | x_t, \lambda_t) - \lambda_{t+1}]$. Intersections with the 45° line represent fixed-point solutions to (16).

Figure 1.



The analysis of existence of multiple equilibria is as follows. Considering that $f(\cdot)$ reaches its maximum at $f(0)$, if $f(0) < 1$ the slope $\frac{\partial C}{\partial \pi}$ can never be greater than one and only one fixed point equilibrium is feasible. This situation is depicted by the curve C^0 . It follows that $f(0) > 1$ is a necessary condition for multiplicity of equilibrium. A sufficient condition can be used by noticing that a healthy economy

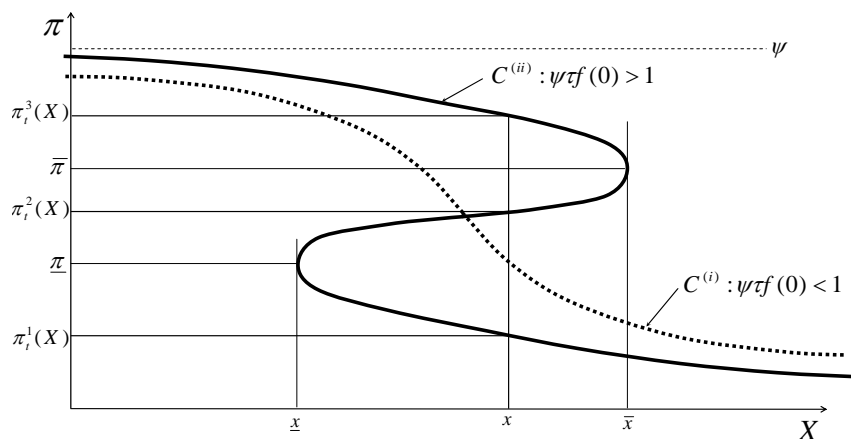
$$\lambda_{t+1} = \left(A_0 + \sum_{i=1}^N A_i \lambda_{t-i+1} \right)$$

characterised by a path of high level of fundamental variable has a lower probability of devaluation C given π , i.e. higher levels of fundamental variable shift the $C(\pi)$ curve to the right in Figure 1. In an extreme case, when the fundamental variable is healthy enough, the economy is immune to crises (i.e. B_{t+1} is positive irrespectively of π) a situation which is represented by curves to the right of \bar{C} in Figure 1. The other extreme case is also possible: B_{t+1} could be negative irrespectively of π , a situation which is represented by curves to the left of \underline{C} . Therefore, necessary and sufficient conditions for multiple equilibria are: (i) $\psi \tau f(0) < 1$, i.e. the distribution of ε_t cannot be too flat or the parameters ψ and τ too small; and (ii) the curve $C(\pi)$ must lie between limits \bar{C} and \underline{C} which means that the fundamentals (x_t, \dots, x_{t-1}) has to be in an *intermediate* level, neither too misaligned nor too close to long-run equilibrium. The continuity of $f(\cdot)$ implies that if conditions (i) and (ii) are satisfied the model has three fixed-point solutions: $\pi^1 = C(\pi^1)$ associated with small or no-devaluation, $\pi^2 = C(\pi^2)$ associated with a moderate devaluation and $\pi^3 = C(\pi^3)$ associated with a strong devaluation. This result has been formally proven in Jeanne, 1997. For more formal models on sunspot equilibria see Jeanne & Masson, 1998; Azariadis & Guesnerie, 1986; Cass & Shell, 1983; and Gali, 1992.

Inchauspe

A more intuitive explanation of how sunspot equilibria emerge can be as follows. Assume that the fundamental variable could be explained by the following simple AR(1) process: $x_{t+1} = x_t + \epsilon_t$, and that the distribution of fundamental shock ϵ_t , ψ and τ are such that allow for $\frac{\partial C}{\partial \pi} > 1$. Then, it is possible to find fundamental boundaries \underline{x} and \bar{x} such that whenever $x_t \in (\underline{x}, \bar{x})$, multiple equilibria arise. These boundaries are associated with $\underline{\pi}$ and $\bar{\pi}$ in Figure 1 and can be found as the two fixed-point solutions of (16) after imposing the tangency condition $\frac{\partial C}{\partial \pi} = 1$. The overall message of this model is that, under certain conditions, multiple equilibria may arise if the fundamental variable lies in a grey zone (\underline{x}, \bar{x}) . However, if the fundamental variable is in a healthy state, no-crisis is the only possible outcome. Likewise, when the fundamentals of the economy are in a weak state, devaluation is a necessary outcome. An alternative graphical representation of this idea is given in Figure 2: whenever x_t lies on the interval (\underline{x}, \bar{x}) three equilibrium levels of π , i.e. three different levels of interest rate, are feasible.

Figure 2.



There are three important features in this model. The first one is that only under certain conditions multiple equilibria are possible. The second important characteristic is that *a priori* this model does not predict which one of three equilibria will prevail. For this reason this model predicts that small events or *sunspots* could shift the economy from one equilibrium to another one. Naturally, it would be interesting to analyse the coordination problems that could move the economy between good and bad equilibria. The informational coordination problem has been recently treated by Angeletos & Werning, 2006, who show that if the interest rate can be used as a signal to convey information among agents in the private sector, a small noise in private information is enough to guarantee multiple equilibria. This result strongly suggests that the basic conclusions of this model are robust to coordination failures. Hellwig *et al.*, 2005, arrive to similar conclusions. These new findings sharply contrast previous results in Morris & Shin, 1998, who had suggested an opposite outcome after assuming that the price system of the economy was exogenous.

4. An Empirical Illustration: The Korean Crisis of 1997-8

The purpose of this section is to introduce detect the presence of multiple equilibria and equilibrium shifts during the South Korean crisis of 1997-8 in accordance to the model that has been introduced beforehand. As explained in Jeanne, 2000, and Jeanne & Masson, 1997, Markov-switching econometric techniques are a powerful tool to test for the presence of multiple equilibria. The hypothesis to be tested can be explained as follows. The economy is characterised by equations (1) through (4). The exchange rate is fixed and all adjustments towards long run equilibrium are done through prices according to equation (5). Due to price rigidities, the adjustment also affects real variables. If certain conditions are satisfied, multiple levels of interest rate i_t^1 , i_t^2 and i_t^3 are possible given the fundamental variable prediction \hat{X}_{t+1} in the actual state of the economy as it is represented in Figure 2. A shift from one rational-expectation interest rate to another one can be represented a shift in the intercept of equation (4) affecting equations (1) through (3) and the intercept of (5). High interest rate may force the policymaker to abandon the peg. Once the peg is abandoned, the dynamics of the model adjust according to (11) and (12) producing an *overshooting* effect in the nominal exchange rate. This series of events is precisely what defines a currency crisis. In the case of Korea, the exchange rate was not strictly fixed and fluctuation bands were allowed (IMF classifies the exchange rate of South Korea as ‘managed floating’ for the period June 1982 – December 1997⁽ⁱⁱⁱ⁾). Thus, our empirical estimation will allow exchange-rate fluctuations to absorb *part* of the interest rate pressure.

An appropriate empirical approach to deal with the dynamic evolution of expectation shifts would be a Markov-switching vector autoregression with switching intercepts. The general definition of the model is given by the following Markov-switching vector autoregression with exogenous variables, i.e. MS(M)-VARX(N,L):

$$Y_t = A_0(M_t) + A_1 Y_{t-1} + \dots + A_N Y_{t-N} + B_1 X_{t-1} + \dots + B_L X_{t-L} + U_t, \quad (17)$$

Where $Y_t = [y_t \ p_t \ s_t]'$ are the endogenous variables, $X_t = [y_t \ m_t \ g_t \ p_t^* \ i_t^* \ R_t \ d_t]'$ are the exogenous variables, $U_t \sim ntd(0, \sigma^2)$, $U_t = [U_t^1 \ U_t^p \ U_t^s]'$, and $\sigma_t = [\sigma_1^2 \ \sigma_p^2 \ \sigma_s^2]'$.

The intercept $A_0(M_t)$ is Markov-switching and takes two values $\{A_0^m\}_{m=1}^2$ as the system switches between regimes $M_t = \{1,2\}$. The transition between states is assumed to be governed by a Markov chain which is discrete-regime, homogenous, stable and of first order:

$$Pr(M_t = j | \{M_{t-1} = i\}_{i=1}^2, \{Y_{t-1} = y\}_{y=1}^2, \{X_{t-1} = x\}_{x=1}^2) = Pr(M_t = j | M_{t-1} = i, \rho), \quad (18)$$

Where ρ denotes the parameters of the regime generating process. The process in (18) is characterised by the transition matrix $P_{2 \times 2} = \{p_{ij} = Pr(S_t = i | S_{t-1} = j)\}$. Kim & Nelson (1999) and Krolzig (1997) show how to make an inference about regime classification and estimate the parameters by using an expectation-maximization recursive algorithm and a special filter and smoother.

Inchauspe

For pure parsimonious efficiency reasons and considering the relatively small number of observations, we will include two Markov-switching regimes rather than three as in the original model. If the hypothesis of this model is right, incorporating two regimes should dramatically improve the explanatory power of the model in comparison to its linear (i.e. single-regime) version. Another justification for including two regimes is only is that the economies being studied here may have switched between two states and not necessarily between the three of them.

The approach used in the VAR estimation is according to Sims, Stock & Watson, 1990. Rather than estimating a large number of complex cointegrating error correction terms, we run a simple vector autoregression with all the ten variable levels, some of them being $I(1)$ and others $I(0)$ processes. It can be shown that any cointegrating relationship existing between the variables can be obtained after reparametrising the model. Furthermore, Krolzig, 1997 (p.303) and Krolzig & Toro, 1998, show that a Markov-switching intercept in a VECM can be associated with shifts in the cointegrating relation and the concept of multiple equilibria.

Following the formulation of the model, the following variables are included. The vector of endogenous variables Y_t contains: nominal interest rate (3-month government bond), natural logarithm of CPI price level and nominal exchange rate against US dollar. The vector of exogenous variables X_t contains all the fundamental variables that defined Z_t (the overall 'fundamental variable' the model). This includes: natural logarithms of GDP, money supply (M2), government spending, US CPI, international reserves, as well as a US 3-month treasury bond interest rate and fiscal surplus/deficit (d). The data has been provided by *DataStream*, *International Financial Statistics* database and official sources.

The results are summarised in the Appendix. We find that, of the two regimes, the model infers that one of them is associated with long periods of tranquillity and the other regime is associated with high speculation explaining the 1997-8 crisis episode (Figure A1). Next, in Figure A2 shows fitted and actual values of interest rate, exchange rate and prices. There are two important noticeable features. The first one is that before the crisis, the mean of interest rate was higher than after the crisis, this is in accordance with our model. The second important feature is that there was an overshooting effect on exchange rate, as it was also suggested in our model.

5. Beyond the Basic Model: Sunspots and Contagion

The last section analysed the 1997 South Korean crisis, but nothing was said about other Asian countries that were also affected by currency crises and how this may have affected South Korea's economy. This additional section fills this gap and extends the basic framework to incorporate different channels of contagion. We also show that the individual study of an isolated country should not be substantially limited by contagion effects. The model is based on Masson, 1999a, 1999b, 2007. We contemplate the possibility of three different channels of contagion. A first type of contagion occurs when countries are affected by *monsoonal effects* in the world economy, i.e. by global events affecting the world economic scenario such as US

Inchauspe

interest rate, oil prices and global recessions. A second channel for contagion is through *spillover effects* which include trade and financial linkages between the countries affected by the crises. Finally, a third channel is *pure contagion*, defined as a co-jump between sunspot equilibrium in each economy. The latter implies the existence of *correlated* sunspot equilibria [as defined in Aumann, 1974].

In what follows, we reduce our framework of analysis to include a single fundamental variable: the balance of payments. The new assumptions can be summarised as follows. There are two countries represented by $\ell = \{a, b\}$. Each country faces a trade balance T_t^ℓ , and has a level of external debt equal to D_t^ℓ . Furthermore, each country pays an interest rate i_t^ℓ on its stock of external debt. This domestic real interest is defined as $i_t^\ell = i_t^* + \pi_t^\ell \delta_t^\ell$, where i_t^* represents the international risk-free interest rate, $\pi_t^\ell \delta_t^\ell$ is a compensation for expected depreciation, δ_t^ℓ is the expected devaluation size and $\pi_t^\ell = \pi(i_t^\ell - i_t^* | \mathcal{F}_t)$ is the probability of devaluation. Denoting R the level of international reserves, a simple representation of the balance of payment for each economy can be written as: $R_{t+1}^\ell - R_t^\ell = T_t^\ell - i_t^\ell D_t^\ell$. Finally, it is assumed that both countries are under a fixed exchange-rate scheme and devalue their currency if, and only if, the level of international reserves drops below a critical value \bar{R} . Assuming that this critical level of reserves is zero, the policymaker of country ℓ devalues the currency at period $t+1$ whenever,

$$R_t^\ell - T_t^\ell - i_t^\ell D_t^\ell = R_t^\ell - T_t^\ell - (i_t^* + \pi_t^\ell \delta_t^\ell) D_t^\ell \leq 0, \quad (19)$$

To concentrate on the role of expectations and shocks, we assume that T_t^ℓ , D_t^ℓ , R_t^ℓ , i_t^* and δ_t^ℓ are exogenously given. Using rational expectations, the private sector of each economy ℓ estimates a probability of devaluation π_t^ℓ which is transmitted through the money market through $i_t^\ell(\pi_t^\ell)$ and affects $R_{t+1}^\ell(\pi_t^\ell)$ and therefore the policymaker's devaluation decision.

What follows is a re-interpretation of Jeanne, 1997. Equation (19) can be clearly associated with the policymaker's net benefit function. The 'fundamental' variable is given by $X_{t+1}^\ell = R_{t+1}^\ell + T_{t+1}^\ell - i_{t+1}^\ell D_{t+1}^\ell$, the 'expectation' variable is given by π_t^ℓ , and $\lambda_t^\ell = \delta_t^\ell D_t^\ell$. The decision about whether or not to devalue is taken by the policymaker in period $t+1$. The agents in the private sector of the economy form their expectations in period t knowing the policymaker's reaction function and forecasting the macroeconomic fundamentals of the economy. It is assumed that private sector of the economy ℓ can forecast the macroeconomic fundamentals in an appropriate way, i.e. the predictor $\hat{X}_t^\ell = E_t(X_{t+1}^\ell) = R_t^\ell + E_t(T_{t+1}^\ell) - i_t^\ell D_t^\ell$ yields a forecast error $e_t^\ell = \hat{X}_t^\ell - X_{t+1}^\ell$ which is $iid(0, \sigma_{e_t^\ell}^2)$ with density $f(\cdot)$ and c.d.f. $F(\cdot)$. Under rational expectations, the probability of devaluation which is expected by the private sector must be equal to objective probability of devaluation:

Inchausepe

$$\pi_t^f = \Pr[R_t^f + T_{t+1}^f - (i_t^f + \pi_t^f \delta_t^f) D_t^f \leq 0] = \Pr[s_t^f \leq \lambda^f \pi_t^f - \hat{\lambda}_t^f] = F(\lambda^f \pi_t^f - \hat{\lambda}_t^f), \quad (20)$$

As in Jeanne, 1997, Equation (20) may have multiple equilibria if certain conditions are satisfied. Multiple equilibria are more likely when λ^f is high, i.e. when external debt is high. Another necessary condition requires the macroeconomic fundamental to be in an intermediate state; in this model, this means that the trade balance needs not have large deficits or surpluses, i_t^f needs not be too large, and the level of international reserves does not have to be too large.

The novelty of this model arises when is trade link is incorporated in the model. Let us assume that countries a and b export similar products and compete for the same external market. A competitive devaluation in b would be equivalent to a *shock* in the trade-balance of country a . More formally, a devaluation in country b causes a an improvement of its own trade balance of $\Delta T^b(\Delta s^b)$ and a deterioration of country a 's trade balance equal to $-\zeta \Delta T^b(\Delta s^b)$, where $\zeta > 0$ is a coefficient that embodies the degree of substitutability between exports from both countries, the relative export share in the global economy and other market conditions. Using these definitions it is possible to re-write (2) for each country in the following way:

$$(21) \quad \left\{ \begin{aligned} \pi_t^a &= [(1 - \pi_t^b) \Pr[R_t^a + T_{t+1}^a - (i_t^a + \pi_t^a \delta_t^a) D_t^a \leq 0] \\ &\quad + \pi_t^b \Pr[R_t^a + T_{t+1}^a - \zeta \Delta T^b(\Delta s^b) - (i_t^a + \pi_t^a \delta_t^a) D_t^a \leq 0]], \\ \\ \pi_t^b &= [(1 - \pi_t^a) \Pr[R_t^b + T_{t+1}^b - (i_t^b + \pi_t^b \delta_t^b) D_t^b \leq 0] \\ &\quad + \pi_t^a \Pr[R_t^b + T_{t+1}^b - \zeta \Delta T^a(\Delta s^a) - (i_t^b + \pi_t^b \delta_t^b) D_t^b \leq 0]], \end{aligned} \right.$$

(21')

Considering the equation system formed by (21) and (21'), it is possible to identify three types of contagion:

(i) *Contagion through the trade balance.* In equation (21) it is clear that if a devaluation had occurred in country, this would imply a *shock* $-\zeta \Delta T^b(\Delta s^b)$ in country a 's trade balance which deteriorate the fundamental variable of a 's economy. If this shock is large enough, a 's economy could potentially from the 'good equilibrium' situation to the 'multiple equilibrium situation' or even to a bad equilibrium. As before, a deterioration of fundamental variable shift the C curve in Figure 1 to the left. Other type of spillovers affecting global output may have similar effects.

(ii) *Contagion through Monsoonal Effects*. This is a different type of ‘contagion’ which arises from changes in the economic conditions of the global arena that affect various countries. The changes can be associated, for example, with US monetary policy, oil prices, a global credit crunch and other supply shocks. If these shocks increased the international risk-free interest rate i_r^* , this could potentially move the economies of countries a and b from the good equilibrium to a situation of multiple equilibria or even bad equilibrium. It is worth noting that for this type of contagion the economies a and b do not have to be related to each other by means of trade, business or regional links.

(iii) *Pure Contagion*. This type of contagion is simply defined as a defined as a co-jump between two sunspot equilibria in each economy, i.e. $(\pi^a, \pi^b) \rightarrow (\pi^{a'}, \pi^{b'})$. Conceptually, this category embodies all other types of contagion. A common claim in the literature is that emerging countries affected by contagion effects have common lenders or common investors such international investment banks and multinational firms. A shift in the expectations of these common lenders or investors would affect of the countries that are part of the global portfolio of these firms and, given the particular economic conditions of each country, some of them may incurred in crises. It is worth noting that a coordination motive is not necessary in this type of situations and that the countries affected by pure contagion need not be economically related. A final remark is that this model does not impose any limiting restriction that would suggest that an individual analysis of a country affected by contagion is inappropriate. The trade balance, the international interest rate and the sunspots contain all the relevant information about contagion so a model such as the one presented in the main section is not necessarily limiting.

6. Concluding Remarks

Currency crises have become a complex phenomenon. This paper sheds some light on the possibility of sunspot equilibria and how they would affect a macroeconomic scenario. Sunspots explain how small events which shift expectations could move the economy towards a bad equilibrium and make these expectations self-validate. However, certain macroeconomic conditions have to be satisfied in order to have multiple equilibria. We have shown how these situations emerge in a macroeconomic context and how some of the recent currency crises can be explained. We have also we analysed the model using data for the 1997-8 crisis in South Korea as an empirical illustration.

End Notes

(i) In first-generation models of currency crises, this term is typically non-stationary and steady-deterioration in the fundamental variable implies that a one-off exchange rate adjustment.

Inchauspe

(ii) In a similar but more specific model, Obstfeld (1996) assumes that the fundamental shock is *uniformly* distributed over some interval and arrives to similar analytical conclusions.

(iii) Source: IMF, *Annual Report on Exchange Arrangements and Exchange Restrictions*, various issues.

References

Aghion, P., Bacchetta, P. & Banerjee, A., 2001, 'Currency Crises and Monetary Policy in an Open Economy with Credit Constraints', *European Economic Review*, Vol. 45, No. 7, pp.1121-1150.

Angeletos, G., Werning, I., 2006, 'Crises and Prices: Information Aggregation, Multiplicity and Volatility', *American Economic Review*, Vol. 95, No. 5, pp.1720-1736.

Azariadis, C. & Guesnerie, R., 1986, 'Sunspots and Cycles' , *Review of Economic Studies*, No. 53, pp. 725-736.

Cass, D. & Shell, K., 1983, 'Do Sunspots Matter?', *Journal of Political Economy*, No. 91, pp.193-227.

Dornbusch, R., 1976, 'Expectations and Exchange Rate Dynamics', *Journal of Political Economy*, No. 84, pp.1161-1176.

Gali, J., 1992, 'Local Externalities, Convex Adjustment Costs and Sunspot Equilibria', *Journal of Economic Theory*, No. 64, pp.242-252.

Flood, R. & Garber, P. & Kramer, C., 1996, 'Collapsing Exchange Rate Regimes: Another Linear Example', *Journal of International Economics*, No. 41, pp. 223-234.

Hellwig, C., Mukherji, A., Tsyvinski, A., 2005, 'Self-Fulfilling Crises: The Role of Interest Rate', *National Bureau of Economic Research*, Working Paper 11191.

Jeanne, O., 1997, 'Are Currency Crises Self-Fulfilling? A Test', *Journal of International Economics*, No. 43, pp. 263-286, November.

Jeanne, O., 2000, 'Currency Crises: A Perspective on Recent Theoretical Developments', *Special Papers in International Economics*, No. 20, Princeton University Press.

Jeanne, O. & Masson, P., 1998, 'Currency Crises, Sunspots and Markov-Switching Regimes', *Centre for Economic Policy Research Discussion Paper* No. 1990.

Kim, C., Nelson, C., 1999, State Space Models with Regime Switching, Massachusetts Institute of Technology Press, Cambridge, Massachusetts.

Krolzig, H.-M., 1997, Markov-Switching Vector Autoregressions. Modelling, Statistical Inference and Applications to Business Cycle Analysis, Springer-Verlag, Berlin.

Inchauspe

Krolzig, H.-M., Toro, J., 1999, 'A New Approach to the Analysis of Shocks and the Cycle in a Model of Output and Employment', *European University Institute*, Working Paper ECO 99/30.

Krugman, P., 1979, 'A Model of Balance of Payments Crises', *Journal of Money, Credit and Banking*, Vol. 11, No.3, pp. 311-325.

Martinez Peria, M., 1998, 'A Regime Switching Approach to the Study of Speculative Attacks: A focus on EMS crisis'. In: Hamilton, J., Raj, B. (Eds.), (2002), Advances in Markov Switching Models, Physica-Verlag, Berlin.

Masson, P., 1999a, 'Contagion: Macroeconomic Models with Multiple Equilibria', *Journal of International Money and Finance*, Vol. 18, No. 4, pp.587-602.

Masson, P., 1999b, 'Contagion: Monsoonal Effects, Spillovers and Jumps between Multiple Equilibria'. In: Agenor, P., Miller, M., Vines, D & Weber, A. (Eds.) (1999), The Asian Financial Crisis: Causes, Contagion and Consequences, Cambridge University Press, Cambridge.

Masson, P., 2007, Lectures in International Finance: Crisis, Coordination, Currency Unions and Debt, World Scientific Publishing Co., New Jersey,

Morris, S. & Shin, H., 1998, 'Unique Equilibrium in a Model of Self-Fulfilling Currency Attacks', *American Economic Review*, 88-3, pp. 587-597.

Obstfeld, M., 1996, 'Models of Currency Crises with Self-Fulfilling Features', *European Economic Review*, No. 40, pp.1037-1047.

Obstfeld, M. & Rogoff, K., 1996, Foundations of International Macroeconomics, The MIT Press, Cambridge, Massachusetts.

Rogoff, K., 2002, 'Dornbusch's Overshooting Model after Twenty-Five Years', IMF Working Paper 02/39.

Sims C., Stock, J. & Watson, M., 1990, 'Inference in Linear Time-Series Models with some Unit Roots', *Econometrica*, Vol. 58, No. 1, pp. 113-144.

Wickens, M., 2008, Macroeconomic Theory: A Dynamic General Equilibrium Approach, Princeton University Press, New Jersey.

Appendix

Table A1 - MS-VAR estimation summary.

<i>Sample</i>	Q1:1984 – Q2:2007
<i>Regimes</i>	M=2
<i>Lags</i>	N=2, L=3
<i>Information Criteria</i>	Akaike: 7.706, Schwarz: 11.238, Hannan-Quinn: 9.131
<i>I(0) Processes</i>	<i>g, b</i>
<i>I(1) Processes</i>	<i>i, p, s, m, i*, p*, R, d</i>
<i>MS-VAR Log-Lik</i>	-222.6228
<i>Linear Model Log-Lik</i>	-242.2808
<i>Transition Matrix</i>	[0.0572 0.7471] [0.9428 0.2529]
<i>Regime 1 Average Duration</i>	17.48 quarters
<i>Regime 2 Average Duration</i>	3.95 quarters

Figure A1 –Markov-switching regime classification.

Inchauspe

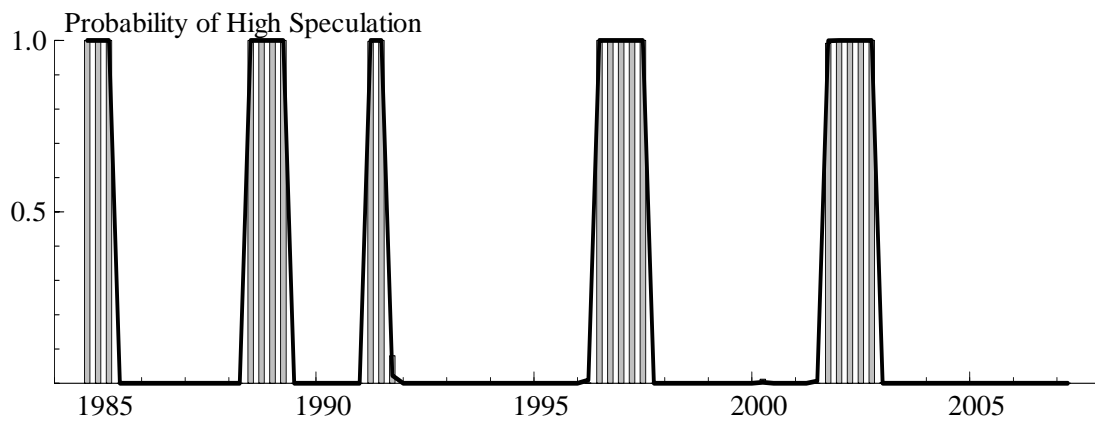
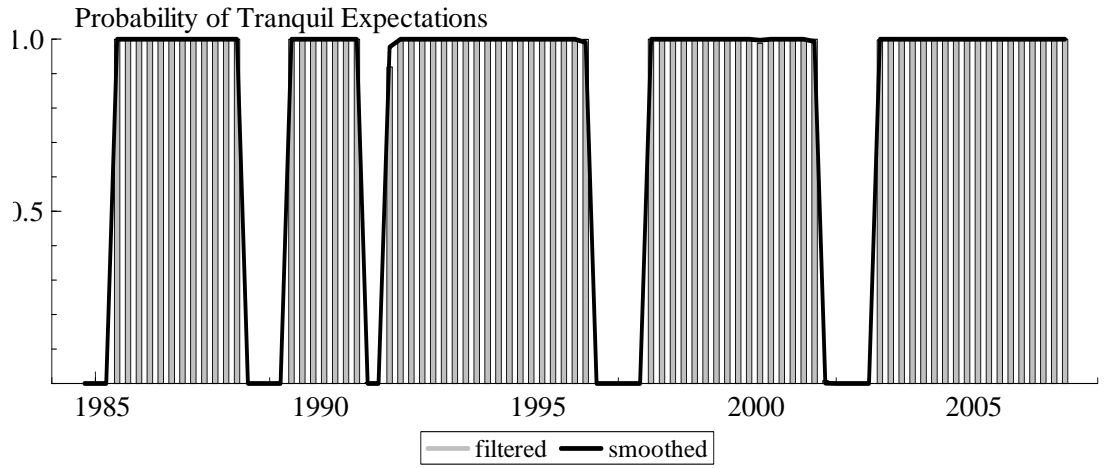


Figure A2 – Fitted and actual values of interest rate, exchange rate and

Fig

Inchauspe

prices.

