Modeling currency instability: The 1997 Asian crisis re-examined

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Abstract

The 1997 Asian crisis triggered major breakthroughs in ways in which financial vulnerability, and in particular currency crises, are modeled and explained. This paper discusses some of these developments in three steps. First, a stylized simple model explaining *self-fulfilling* crises is presented. Secondly, this model is used as a framework to analyze hypotheses which are often found in the literature and their implications for financial instability. The third contribution involves the application of Markov-switching multivariate techniques to empirically examine the main model. *Inter alia*, issues such as information structure, expectations, coordination failure, sunspots, financial regulations and contagion are explored.

JEL Classification: F31, F34, G14.

Keywords: currency crisis; Asian crisis; self-fulfilling; multiple equilibria; financial instability; Markov-switching.

1. Introduction

The purpose of this paper is to show the importance and usefulness of a simple self-fulfilling currency crisis model for providing better insights into financial instability. To do this, a simple theoretical model and its empirical support will be introduced. As we go through this process, we will review some of the most important contributions in currency crisis theory since the 1997/8 Asian crisis. Organizing ideas around a currency crisis model can bring various advantages in understanding sources of financial instability such as: self-fulfilling expectations, coordination failure, role of information, financial regulations, maturity and currency mismatches, indebtedness and contagion, among other issues.

The 1997/8 Asian crisis was a major defining moment for both theoretical and empirical researchers. After general economic deregulation and integration into the world economy by Asian countries in the 1980s, the collapse of some of these countries in the late nineties took most economists by surprise. The complex market failures revealed in this crisis have been an important source of contributions ever since.

The Asian crisis must be understood in its context. The currency crises of the 1970s and the 1980s were very different to the Asian crisis. In the 1980s, roughly 80% of international capital flows were sovereign loans[1], and therefore currency crises were directly linked to government mismanagement or time-inconsistent macroeconomic policies. A model explaining this type of crisis can be found in Krugman (1979); models of this kind are known as 'first-generation' models of currency crises. In the 1990s, thanks to capital account liberalizations, *private* flows of capital came to dominate public flows. In addition, the developments in information technology and new financial instruments exacerbated the role of private investors. A turning point came with the speculative attack on various European currencies in 1994, which broke the European exchange rate mechanism based on fluctuation bands. This experience opened the door to models such as Obstfeld (1996) and subsequent 'second-generation' models which explained private speculation and self-fulfilling crises. However, in 1997 the Asian crisis brought even more complex micro-level problems and market failures, such as currency and maturity mismatches, balance-sheet problems and financial regulations. The models dealing with these issues are known as 'third-generation' models. We believe that the problems involved in the Asian crisis can be better understood by organizing these ideas around a multiple equilibria, self-fulfilling expectation model. It is worth noting that a currency crisis is generally linked to a fixed, or somehow controlled, exchange rate which eventually breaks down in a sudden move. When the exchange rate is not allowed to move freely, the macroeconomic adjustments and expectations are transmitted through the interest rate. Table 1 shows how during the 1997 Asian crisis were tightly-controlled if not fixed[2].

Given this introduction, the balance of the paper is organized as follows. Section 2 presents a formal model of self-fulfilling crises which is kept as simple as possible. Section 3 provides some insights into some of the problems which occurred during the Asian crisis and are often associated with financial instability. The next section provides empirical evidence on expectation-dependent economic systems which are consistent with the model of section 2. Least but not last, we arrive at conclusions in section 5.

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[1] See Tirole (2002).

[2] Although controlled exchange rates could be an analytically limiting feature, intuition suggests that events such as the sub-prime crisis that occurred in the USA during 2007 share some of the properties of these models.

Country	Exchange Rate Arrangement Classification
Hong Kong	Currency board pegged to US dollar, 1982:7 -Present
Indonesia	Managed floating, 1983:12 – 1997:7 Independently floating, 1997:8 – 2001:9
Korea	Managed floating 1982:06 – 1997:11 Independently floating 1984:11 - Present
Malaysia	Peg to a basket of currencies, 1975:9 – 1993:6 Managed floating, 1993:6 – 1998:9 Peg to US dollar 1998:9 - Present
Philippines	Independently floating, 1984:11 – Present
Singapore	Managed floating, 1987:12 - Present
Taiwan	Managed floating 1989:4 - Present
Thailand	Peg to multiple currencies, 1984:11 – 1997:6 Independently floating 1997:7 – 2001:9

Table 1 – Exchange rate arrangements in countries affected by the 1997 Asian crisis. Sources: IMF, *Annual Report on Exchange Arrangements and Exchange Restrictions*, various issues.

2. The Model

Most multiple-equilibria models of currency crises consist of three elements: a bond market, a policymaker net benefit function, and an equilibrium selection device [see Jeanne (2000) for a review of some of these models]. While containing these elements, the proposed model also incorporates its own characteristics. Initially, it will be assumed that bond traders have perfect information about the future of the economy. Under certain conditions, this assumption implies that there is a continuum of equilibria where a crisis may, but need not, happen. Interestingly, the probabilities of being in the crisis (or non-crisis) equilibrium can be described by a Markov chain conditional on the fundamentals of the economy. Unlike other models, the probability of being in the crisis equilibrium increases as the macroeconomic fundamentals deteriorate. The equilibrium selection assumption and alternative postulates will be discussed later. The model will be keep as simple and intuitive as possible.

2.1. The Bond Market

The first component of the model is the bond market. We assume that a country's government can sell bonds and in the process collect X units of local currency. Repaying this debt has a value $D \geq X$. Bonds are sold in a competitive auction whose bidders are a continuum of foreign investors. These investors are assumed to have perfect information about the future of macroeconomic fundamentals, other investors, and the government's decision-making problem, so that the market-determined interest rate will reflect the exact devaluation risk (this assumption will be modified later). The market clearing condition implies:

$$X = pD \ , \tag{1}$$

Here $p \in [0,1]$ stands for both the bond price and the probability of no-devaluation. It is assumed for simplicity that investors face no opportunity cost. The interest rate is implicitly embodied in p and is inversely related to it. A high interest rate is associated with a high probability of devaluation (or a low probability of no-devaluation), i.e. the value of p is close to zero. If investors foresee a strong macroeconomic position, on the other hand, they will demand a lower interest rate and p will be close to 1. The assumption behind this bond market condition is that the government can make use of fiscal policy in times of upheavals at a cost that is market-determined by well-informed investors.

2.2. The Policymaker's Net Loss Function

The second step in building the model is to introduce a rule by which the policymaker will decide if she should devalue the currency or not. We assume that the exchange rate is initially fixed or tightly controlled (as was the case before the Asian crisis occurred). In each period, the government decides whether to devalue or not, by evaluating the net loss of keeping the peg compared with the net loss of devaluation. The policymaker's net loss function for keeping the exchange rate fixed is defined as:

$$L^{Fixed} = \sum_{i-1}^{h} a^i (Y^i - \overline{Y}^i)^2 d^i + (D - X), \tag{2}$$

The first term in the r.h.s. of (2) represents squared deviations of macroeconomic fundamentals Y^i from a desirable level $\overline{Y}^i$, scaled by some parameters $a^i > 0$ which make them comparable and weight government's utility. Squares were introduced to penalize large deviations. The parameter d^i corrects signs: $Y^i > \overline{Y}^i$ means that the macroeconomic fundamental *i* is in a strong position, so $d^i = -1$ indicates a benefit for the policymaker; similarly, $d^i = 1$ when $Y^i < \overline{Y}^i$. The macroeconomic fundamentals entering Equation (2) are those which affect the policymaker's utility and her decision on devaluation. Typically, these fundamentals include unemployment, public debt, trade balance, level of international reserves, inflation and external debt. The second term of r.h.s. of (2) is much more interesting. Having assumed that monetary policy is committed to keeping the exchange rate fixed, the policymaker can only use fiscal policy to alleviate negative deviations of fundamental variables. Using fiscal policy, however, comes at a cost which is determined by investors in (1). If investors foresee a pessimistic macroeconomic scenario, the cost of using fiscal policy can be prohibitively high, and for the policymaker it might be more convenient to devalue. For the sake of simplicity and without loss of generality, we can assume that there is only one macroeconomic fundamental, the strength or weakness of which is defined below $\overline{Y}$. Introducing this into (2) and replacing (1) we obtain,

$$L^{Fixed} = a(Y - \overline{Y})^2 + (1 - p)D, \tag{2'}$$

Equation (2') makes explicit how investors' expectations can affect the policymaker's devaluation decision by making fiscal policy more costly. To decide whether to devalue, however, the government also needs to evaluate the flexible exchange rate loss function which is defined as:

$$L^{Flexible} = R + D, \tag{3}$$

The idea behind equation (3) is that whereas the fundamental variable improves following devaluation, there is a significant reputation cost associated with the move. We assume that the macroeconomic fundamental improves, for simplicity to $Y^{Flexible} = \overline{Y}$. After full adjustment of the exchange rate, no devaluation is expected so *p*=1 and the government can borrow at the international interest rate. However, there is a strong reputation cost *R* affecting money demand confidence, consumption, and business climate in the country in question.

2.3. Equilibrium Outcomes

The next step is to determine the equilibrium outcome and devaluation decisions by comparing L^{Fixed} with $L^{Flexible}$. We consider three situations,

> <u>I. Necessary devaluation</u>, $Y < Y_1$. Devaluation occurs if $L^{Fixed} > L^{Flexible}$. Then, there exists a certain point Y_1 under which devaluation occurs necessarily, i.e. independently of the investors' expectations *p*,

$$a(Y-\bar{Y})^2+(1-p)D>R+D\ , \qquad \text{for all } Y<Y_1 \text{ and all } p\in[0,1].$$

In this case, expectations do not matter as this result is independent of *p*. Furthermore, under the assumption of perfect foresight previously introduced, we have $p=0$.

<u>II. No devaluation</u>, $Y>Y_2$. On the other hand, we may have the opposite extreme case. If the economy is healthy enough, the policymaker will never devalue and this result is independent of *p*:

$$a(Y-\bar{Y})^2+(1-p)D<R+D\ , \qquad \text{for all } Y>Y_2 \text{ and all } p\in[0,1].$$

In addition, if we assume perfect foresight, then $p=1$.

<u>III. Multiple equilibria</u>, $Y_1\le Y\le Y_2$. This case is much more interesting. When the state of the macroeconomic fundamental is in a 'grey zone', the outcome may not be unique. In this case, how L^{Fixed} compares to $L^{Flexible}$ will depend on the expectations of the market, that is, on the value of *p*,

$$a(Y-\bar{Y})^2+(1-p)D>R+D, \text{ if and only if, } p<\bar{p}.$$
$$a(Y-\bar{Y})^2+(1-p)D<R+D, \text{ if and only if, } p>\bar{p}.$$

Where the boundary $\bar{p}$ is,

$$\bar{p}=\bar{p}(Y)=aY^2-(2a\bar{Y})Y+[a\bar{Y}^2-R], \tag{4}$$

An important implication of the fundamental variable being in the grey zone is that whether a crisis occurs or not depends on *p,* which is determined by private investors. In this case, the government plays a passive role and is at the mercy of the expectations of international investors.

Under the assumptions of complete information, perfect foresight and no coordination problems, investors will charge exactly the price $\bar{p}$ on each bond and the government will be indifferent between pegging and floating the currency whenever the fundamental is on the segment $[Y_1,Y_2]$. However, any minimally small shock or '*sunspot*' affecting $\bar{p}$ would trigger a crisis.

Crises could therefore be *self-fulfilling*, in the sense that if investors were pessimistic and estimated a probability of no devaluation *p* slightly smaller than $\bar{p}$, their beliefs would self-validate and a crisis would occur. The opposite is also true: optimistic expectations could validate themselves. Figure 1 summarizes all the previous results. The curve AD represents sunspot equilibria in which the government is indifferent between devaluing and floating. Bond prices in the intervals $[0,p_1]$ and $[p_2,1]$ are not consistent with rational expectations. Neither devaluation nor no devaluation is a convex set, but if we consider the grey zone only, then no devaluation is a convex set. To interpret it, one can think of the net loss function as the policymaker's utility function depending on two 'goods' or control variables which are *Y* and *p,* subject to constraints. Then, the government shows preference for no devaluation. These results have been source of discussions in the literature and their plausibility will be discussed in next section. Before that, we include a last sub-section with focus on some properties and extensions of this model.

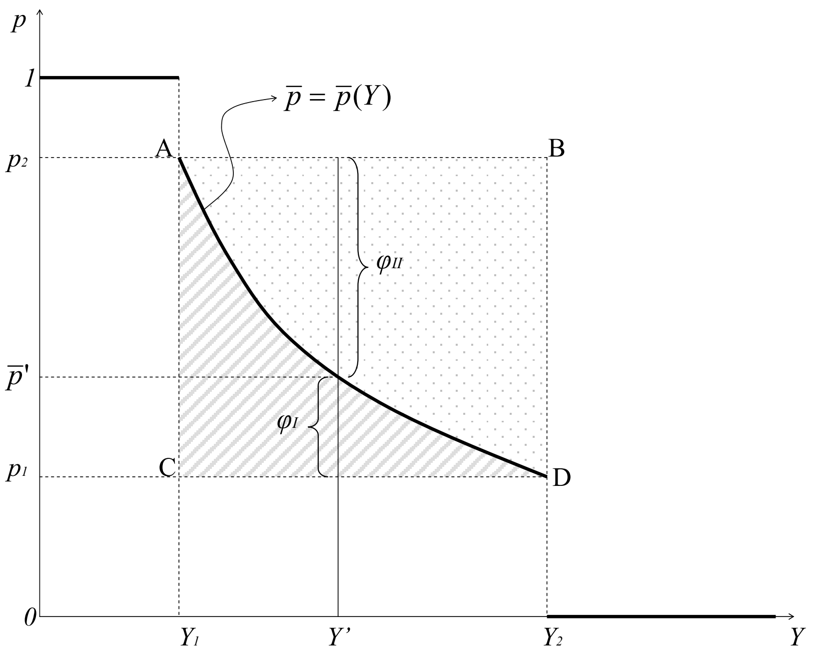

Figure 1.

2.4. Extension of the Model

The results and the structure of the model should not surprise those who are familiar with the literature. Many fundamental-specific models in the literature can be interpreted as special cases of the model presented above, although the equilibrium selection mechanism may vary. The most common case considers unemployment or low activity as the macroeconomic fundamental bringing multiple equilibria, examples of this can be found in Obstfeld (1996), Ozkan & Sutherland (1998) and Jeanne (2000). Further examples consider public debt self-fulfilling crises, these models are found in Cole & Kehoe (1996) and Calvo (1988). A foreign-imported inflation model is given in Andersen (1998). A level of international reserve driven model is presented in Obstfeld (1986, 1996). External debt crises are analyzed in Velasco (1996), and the list goes on. In some of the models listed above, the macroeconomic fundamental may depend on the interest rate, meaning that p no longer enters additively into the government's loss function. Finding fixed-point solutions can be more difficult but does not modify the general result. A formalization of this abstract idea in a general sunspot-equilibria model can be found in Jeanne & Masson (1998).

From now on, we concentrate exclusively on the equilibrium determination in cases where $Y \in [Y_1, Y_2]$. In our model, we initially assumed that investors and the government had perfect foresight and knew each other's information set and reaction function. This implied that the government would be indifferent between devaluing and floating in the grey zone. This was represented by line AD in Figure 1. In reality, however, these assumptions are very unlikely to hold and we should consider alternatives. Dropping these assumptions means that any point inside the ABCD box in Figure 1 is attainable. An *endogenous equilibrium selection mechanism* chooses points inside this box.

A first, natural extension of the basic model consists of basic modifications. Let us assume that: (i) investors know that the macroeconomic fundamental will be on the grey zone but they cannot foresee its value: in other words, we let Y be evenly distributed on $[Y_1, Y_2]$; (ii) The government does not necessarily devalue if L^{Fixed} is marginally greater than $L^{Flexible}$ and the economy is in the grey zone; however, if it persists in this state in next period, a devaluation will become more likely; and (iii) investors do not know the actual government's loss function *ex ante*, but are informed about whether $L^{Fixed} > L^{Flexible}$ in the previous period by observing the news. To formalize these ideas it is useful to consider that points to the left of AD in Figure 1 are associated with devaluation and *vice versa*. We start by considering assumption (i) only. Given this assumption (i), the *ex ante unconditional* probability of crisis is given by the normalization of the area ABD into the $[p_1, p_2]$ probability space,

$$\rho_I = \Pr(L^{Fixed} < L^{Flexible}) = \frac{1}{(Y_2 - Y_1)[\bar{p}(Y_2) - \bar{p}(Y_1)]} \int_{Y_1}^{Y_2} (\bar{p}(Y) - p_1) dY, \quad \text{crisis,}$$

$$\rho_{II} = (1 - \rho_I), \quad \text{no crisis,} \qquad (5)$$

In addition to this, investors and the government can conjecture the *conditional* probability of crisis for a particular value of the fundamental variable. For example, in Figure 1, if *Y=Y'* the conditional probability of crisis and no crisis are,

$$\varphi_I = \Pr(L^{Fixed} < L^{Flexible} | Y') = (p_2 - \bar{p}),$$

$$\varphi_{II} = \Pr(L^{Fixed} > L^{Flexible} | Y') = (\bar{p} - p_1), \qquad (6)$$

As can be seen from Figure 1, the conditional probability of crisis increases as the economy approaches the weak state Y_1 and reduces as the fundamental improves. This result is more realistic and this important feature is not shared by many of the models in the literature.

Now we must introduce assumptions (ii) and (iii). If a temporary shock perturbs the economy in a given period, the government may not be willing to devaluate after considering the intertemporal benefits of keeping the peg. Investors, however, being aware of this will revise upwards the probability of crisis. For example, the conditional and unconditional probabilities of crisis when $L^{Fixed} < L^{Flexible}$ in the previous period would be:

$$\varphi_{I,I} = \Pr(L_t^{Fixed} < L_t^{Flexible} | L_{t-1}^{Fixed} < L_{t-1}^{Flexible}, Y_t'), \qquad (7)$$

$$\rho_{I,I} = \Pr(L_t^{Fixed} < L_t^{Flexible} | L_{t-1}^{Fixed} < L_{t-1}^{Flexible}), \qquad (8)$$

When Equation (8) holds over time, the process is said to have a homogeneous Markov property. In terms of our model, fixed transitional probabilities mean that the parameters of the net loss function are fixed over time, which is a plausible assumption. Considering that we only have two possible outcomes, the transition probabilities as defined in (8) can be arranged in the following transition matrix,

$$P = \begin{bmatrix} \rho_{I,I} & \rho_{I,II} \\ \rho_{II,I} & \rho_{II,II} \end{bmatrix} = \begin{bmatrix} \rho_{I,I} & 1 - \rho_{I,I} \\ 1 - \rho_{II,II} & \rho_{II,II} \end{bmatrix}, \qquad (9)$$

The Markov chain represented by (9) is discrete, homogenous and of first order. Naturally, we assume that the chain has no absorbing states and is stable. If the Markov chain is stable, then as $h \to \infty$, P^h converges to some stable probabilities which do not depend on the previous state. These probabilities are called *ergodic* probabilities and can be calculated by solving the eigenvalue problem associated with them. The ergodic probabilities are also equal to (5) by definition. In empirical economics, making use of state-space models, Bayesian analysis and other tools, equations (7), (8) and (9) can be estimated, hence the relevance of introducing the Markov property. The inclusion of Markovian probabilities in currency crises is also seen in Jeanne-Masson (1998), although in a different way.

3. Sources of Financial Instability: Further Extensions of the Basic Model

There are still other endogenous equilibrium selection mechanisms in the literature explaining what happens when the macroeconomic fundamental is in an intermediate state. Some of these mechanisms are directly associated with particular problems bringing financial instability and increasing the risk of currency crises. We will review some of them without major changes in our basic results.

The possibility of *coordination failure* has been frequently discussed, and important contributions have been made in recent years. These models attempt to explain why the economy moves to a bad or Pareto-inferior equilibrium when better options are attainable. A first formal approach to this problem appeared in Morris & Shin (1998). This paper introduced a global game with imperfect information where each investor perceives a private signal about the fundamental with a certain distribution. The model shows that the possibility of multiple equilibria vanishes as the investors are perturbed away from common knowledge. According to this view, what is important is not the amount of information *per se*, but how it affects beliefs about others' actions. As Morris & Shin (1998, p.594) pointed out,

"*A 'grain of doubt', allowing that others may believe that the economy is, in fact, unstable, will lead to a currency crisis even if everyone knows that the economy is not unstable*."

In short, Morris & Shin argue that multiple equilibria are almost impossible in the real world.

This idea has, however, been criticized and challenged recently, particularly in Angeletos & Werning (2006) and in Hellwig *et al*. (2005). Angeletos & Werning argue that Morris & Shin missed an important element: the role of prices, in particular the interest rate. When considering informational problems, the price system can be used as a *public signal to convey information and coordinate actions*. This is especially true for bonds, which are traded on a daily basis. Moreover, in times of financial turmoil, investors follow very closely the news and the interest rate. In Morris & Shin (1998), the interest rate was exogenously given, there was no bond market, and investors had only private signals about the fundamentals. Figure 2 sketches both models. A key difference between the two models is that, whereas Morris & Shin argue that *given* common knowledge smaller private noises make others' actions less predictable (line AB in Figure 2), Angeletos & Werning argue that common knowledge is actually a function of the private signals (line CO). Hellwig *et al*. (2005) and Angeletos & Werning (2006) also show how investors have non-linear demands in the bond market, restoring the possibility of multiple equilibria. Relying on these properties implies that if in our basic model we had included further assumptions on coordination, information structure and signals, the possibility of multiple equilibria could have survived these assumptions. Therefore, when assessing the risk of self-fulfilling crisis, not only the information structure but also the bond market efficiency and leader-follower interdependence structures should be considered.

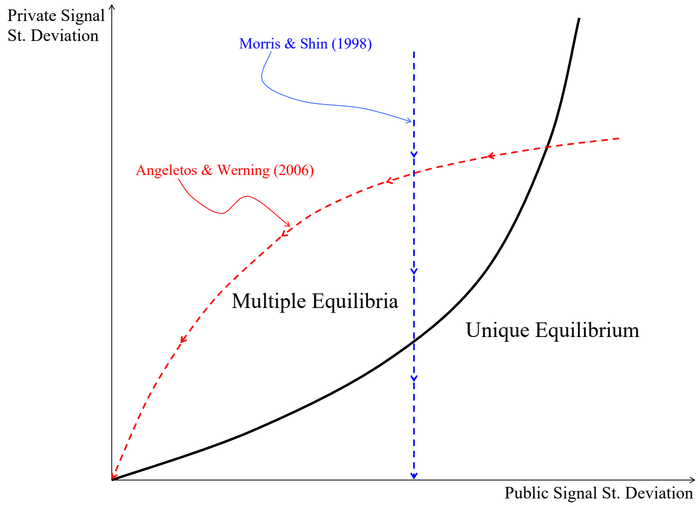

Figure 2.

One issue which received attention during the 1997/8 Asian crisis was the so-called *balance-sheet overlending problem*. Before the crisis, firms tended to overborrow from commercial banks using inflated real-estate properties as collateral. When the currencies collapsed, firms which operated in the internal market found that with their local-currency revenues they were unable to repay their loans denominated in US dollar. This *currency mismatch* is basically a coordination problem similar to the one analyzed above. Investors are again able to coordinate their actions and expectations through prices in financial markets.

Another similar problem is the *maturity mismatch* in financial institutions which borrowed short-term international capital to lend in the long run. In terms of our model, if these coordination failures occurred, they would affect the government net loss function via fundamentals such as activity or unemployment, and also via the interest rate through asset prices.

During the 1997/8 Asian crisis, all these coordination failures exacerbated the effects of the crisis and also made the probabilities of a self-fulfilling crisis more likely. The undesirable effects of currency and maturity mismatches could have been avoided with better *financial and prudential regulations* and *bankruptcy laws*.

A third possible extension of our model would include the possibility of organizations such as the *International Monetary Fund* lending money to the local government. This has three effects in our model. First, it allows for intertemporal allocations of debt and fiscal policy. Second, the money provided by the IMF is typically lent at a rate smaller than market rate p, making the economy less investor-dependent. More specifically, in the latter case the net loss function becomes,

$$L^{Fixed} = a(Y - \overline{Y})^2 + (1 - p)D + D^{IMF} ,$$

This narrows the grey zone of the economy. Despite all these attractive features, Zwart (2007) shows that the IMF intervention may be perceived negatively by investors and have an offsetting impact; this third effect is reflected through a higher value of p. In addition, it is not very likely that the IMF will lend money unconditionally at all times. One reason for this is that the IMF would want to avoid *moral hazard*: if money is lent unconditionally at all times, governments and local agents may find incentives to participate in much riskier activities. On the other hand, a tight lending policy by the IMF affects *optimal resolution* of crises by making them more costly. For all these reasons, the IMF generally has highly discretionary policies.

Finally, an issue of controversy for the Asian crisis has been the *contagion effect*. There exist at least three plausible hypotheses about contagion. The first one is that contagion occurs through the *trade balance*. For example, if by devaluing its currency Thailand became more competitive, a country which exports similar products would need to devalue its currency to keep its trade balance in order. In other words, for a given country, other countries' devaluations can be equivalent to a *ceteris paribus* trade-balance shock. In reality, when a country suffers from this type of problem, the most likely outcome is that investors will anticipate the trade balance shock and force a devaluation before the commercial balance deteriorates. A second hypothesis is *portfolio rebalancing*. If international investors are aware that there might be a certain risk associated with a region of the globe, they may want to re-balance their portfolio globally to diversify their risk exposure more efficiently. Thirdly, contagion may also affect expectations through complex mechanisms. In terms of our basic model, the three cases are shocks on the probability of crisis *p*. Further modeling of contagion and coordination failures exceeds the purpose of this paper. So, now that the main model and its possible extensions have been exposed, we leave further extensions to the mind of the reader.

4. Are Multiple Equilibria Actual? A Markov-Switching Vector Autoregressive Model Examination[3]

In this last section, we provide empirical evidence in favor of self-fulfilling crises. Markov-switching models have been largely used in currency crisis literature. Their attractiveness is that they allow for jumps in the parameters that can be associated with jumps in expectations. There are various ways of introducing Markovian properties. Excellent empirical works have been published, for example, by Martinez-Peria (1998), Jeanne (1997), Fratzscher (2003), Gonzalez-Garcia (1999) and Alvarez-Plata & Schrooten (2003), to mention a few. However, these works can at times be too specific in that they address particular crises in particular countries. The estimations in this section are far less ambitious, as the same simple model was applied to eight different Asian countries. The data were taken from DataStream, International Financial Statistics and World Bank; availability of data was a problem in some cases and the best available frequency was quarterly. Despite all these difficulties, we took long periods and found some support for the basic model used in this paper.

We estimated a *Markov-switching vector autoregressive* (MS-VAR) model, which can be written as,

$$y_t = v(s_t) + A_1(s_t)y_{t-1} + ... + A_p(s_t)y_{t-p} + u_t(s_t)\,, \tag{10}$$

Where $y_t = [y_{1t},..., y_{kt}]'$ is a vector of macroeconomic fundamental variables (including interest rate), $u_t \sim \text{n.i.d.}(0, \Sigma(s_t))$, and $s_t = 1,2$ are the states associated with crisis and no crisis expectations. Furthermore, the dynamic transition between states is assumed to be governed by a discrete, first-order homogeneous Markov chain as previously explained. A full development of the MS-VAR model and its properties is given in Krolzig (1997) and in Kim & Nelson (1999). The stability and stationarity of the model is assured by the following *sufficient* conditions: (i). Stationarity and stability of the linear VAR model; and (ii) ergodicity and irreducibility (no absorbing states) of the Markov chain.

The analysis is applied to eight Asian countries affected by the 1997/8 crisis: Thailand, South Korea, Malaysia, Hong Kong, Indonesia, the Philippines, Singapore and Taiwan. For each country, a set of fundamental variables was chosen. As suggested by the model in section 2, we chose macroeconomic

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[3] For empirical estimations, the following software has been used,

CATS in RATS, version 2.0, by Dennis, J.G., Hansen, H., Johansen, S. & Juselius, K., Estima 2005.

MSVAR for Ox Programming Language, version 1.31j, by Krolzig, H., 2004.

Ox Programming Language, version 3.4, by Jurgen Doornik, 2004

RATS (Regression Analysis of Time Series), version 7.0, Estima 2005.

variables which exhibit some kind of weakness. The macroeconomic fundamentals chosen for each country are summarized in Table 2. The expression from (10) corresponding to the interest rate looks approximately like Equation (2). The model captures the idea that, as the economy jumps from one regime to another one, multiple values of the interest rate can coexist with the same macroeconomic fundamentals. Further explanatory variables may not be necessary, as the explained variable also appears lagged in the r.h.s. of (10). In addition to these macroeconomic fundamentals and the interest rate, we also included the exchange rate in all cases. Although all these countries had fixed or tightly-controlled exchange rates, small movements in the exchange rate may have absorbed movements in the interest rate in some cases. When the exchange rate is partially fixed, the expectations and the public signal are transmitted through both the interest rate channel and the exchange rate channel. To estimate the parameters of the model, equation (10) is rewritten into its *state-space* representation. A *state* binary vector indicates the state in which the system is. A *space* variable is given by the VAR sub-models resulting after regime classification. The parameters cannot be calculated directly from the log-likelihood function, because it suffers from multimodality and non-standard conditions. Instead, the parameters are estimated with an *expectation maximization* (EM) algorithm. The *expectation* step infers the regime classification or state vector and the conditional probabilities as in (7); this is done aided by the so-called Baum-Lindgren-Hamilton-Kim filter and smoother. The unconditional probabilities and the transition matrix can then be reconstructed. In the *maximization* step, the autoregressive parameters of (10) are estimated. If the expectation-maximization steps are repeated iteratively, the resulting parameters are proved to be asymptotically efficient.

	Sources of Internal Weakness			Sources of External Weakness	
	Output	*Unemployment*	*Budget Deficits*	*Trade Balance*	*International Reserves*
Hong Kong	O	O	X	O	X
Indonesia	X	NA	X	X	O
Korea	O	O	X	O	O
Malaysia	X	NA	NA	O	O
Philippines	X	O	O	O	X
Singapore	X	O	X	X	O
Taiwan	X	O	X	X	O
Thailand	O	O	O	O	O

O: Possible sources of macroeconomic vulnerability; X: Fundamentals in strong position; NA: Not available.

Table 2- Sources of currency instability

In the implementation and testing of the model we took the following steps. The first step consisted of unit root analysis on the variables and detrending them whenever necessary. Dickey-Fuller, McKinnon and Phillips-Perron tests were used when the variables moved smoothly. As for time series which presented abrupt breaks in trend or intercept, we used the Perron (1997) test which allows for three different breaking options. After that, the model was run to choose the number of lags according to Schwarz's and Hannan-Quinn's criteria, and according to lag reduction tests as well. The number of lags varied between 1 and 3. Likelihood ratio tests allowed for misspecification testing on regime-dependence, variable inclusion and regime-conditional heteroskedasticity. The number of regimes was set to two using the economic criterion suggested by sub-section 2.4. Likelihood-ratio tests were also be used to reject VAR linearity, but in this case instead of using a chi-squared critical value we used the Hansen (1992, 1996) test; in all cases we could reject linearity with 95% confidence. Residuals autocorrelation was checked with the Ljung-Box and ARCH tests; this also helped decide whether to allow for regime-dependent heteroskedasticity. Normality was evaluated though the skewness and kurtosis of residuals and the small-sample Shenton-Bowman test. Finally, Markovian ergodicity and irreducibility were tested. Unfortunately, regime-dependence does not allow us to test for Granger causality. No intervention dummy variables were used. A summary of the model, its fitness and Markov probability properties are presented in the appendix. The model performs reasonably well in most cases, especially in those countries which were heavily affected by the crisis. Considering the limitations of the general approach used in this section, the results are satisfactory and show the usefulness of Markov-switching models to identify expectation-dependence. The timing and probabilities of being in one state or the other were inferred by the model and can be easily identified with crisis periods. The results give support to the model described in Section 2.

The MS-VAR model as introduced in (10) may not be econometrically appropriated in some cases. It may happen that some fundamentals are *cointegrated*, i.e. they may not be stationary but share a relationship which is stationary. Excluding cointegrating relationships is misleading, therefore a final step was to test for cointegration. In particular, we were concerned about parallel movements between the interest rate and the exchange rate. With Johansen's test, we could not reject cointegrating relationships for Thailand and Taiwan. As explained in Krolzig (1997) and in Krolzig & Toro (1999), it is possible to estimate a *Markov-switching vector error correction model* (MS-VECM) in two steps. In the first step, a standard VECM is estimated. In the second step and keeping the cointegrating relationship fixed, all the parameters (including an unrestricted intercept) are re-estimated allowing for regime-dependence. The effects of the Markov-switching intercept will then have to be absorbed by either a common-trend mean or equilibrium means. As cointegrating relationships are often interpreted as long-run equilibria, this model provides stronger support for the idea of multiple equilibria. The results are summarized in the Appendix. Interestingly, the regime classification and Markovian probabilities are strongly associated with the 1997/8 crisis.

5. Conclusions

The ways financial instability, and in particular currency crises, are understood have been changing dramatically since the 1997/8 Asian crisis. In a simple theoretical framework, we showed how multiple equilibria can emerge either as sunspots or under imperfect-information and uncertainty conditions. The idea of multiple equilibria and self-fulfilling crises is also supported by empirical evidence with Markov regime-switching models. Finally, this paper suggests that some sources of financial instability such as coordination failure, information structure, public signals, currency and maturity mismatches, financial regulations, international contagion and exchange-rate risk in general can potentially be better understood if considered in the context of currency crises.

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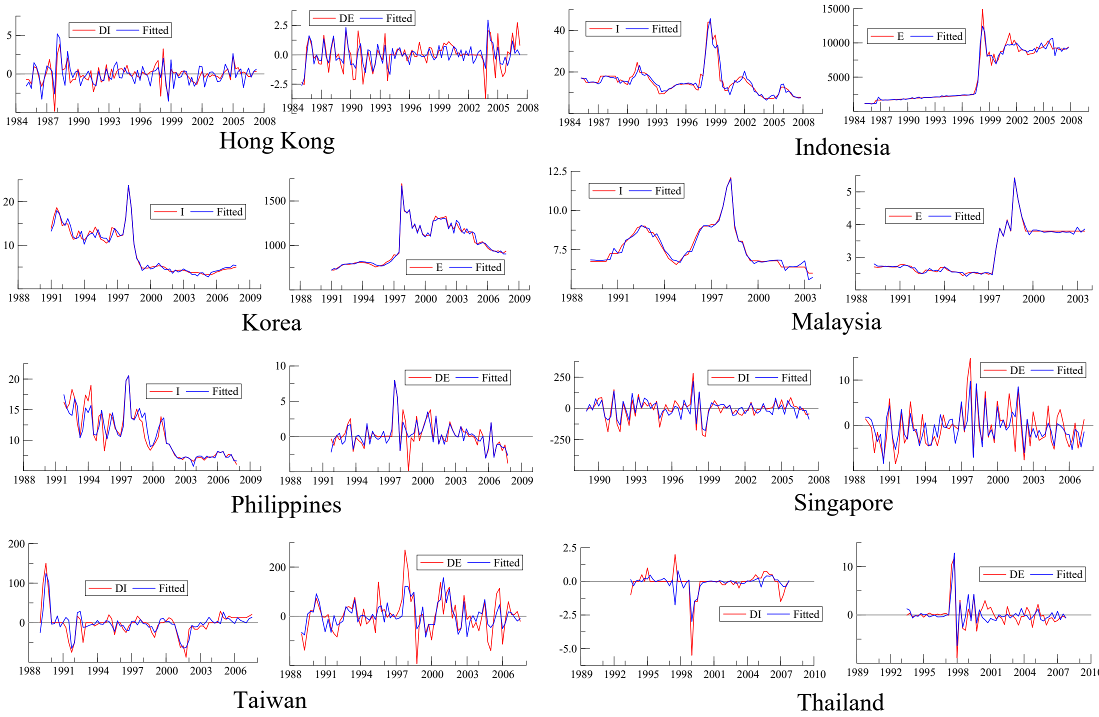
Appendix

Table A.1 - MS-VAR estimation results.



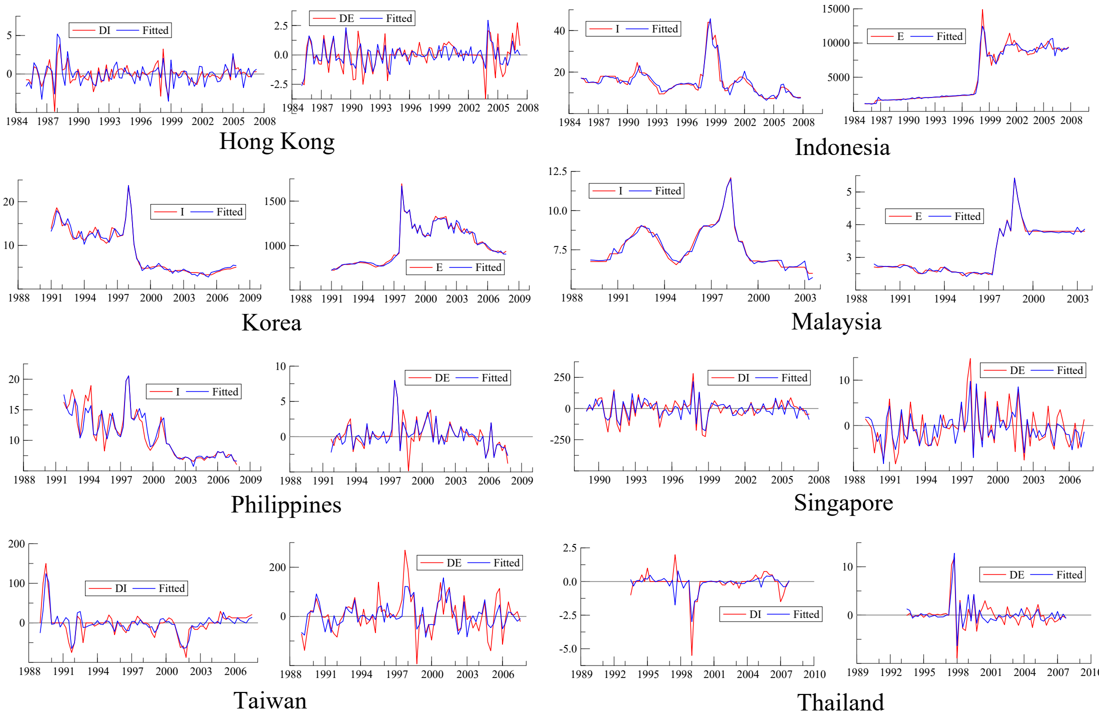


Figure A.1 – Fitted and actual values of interest rate and exchange rate (in levels when they are *I(0)* and in first difference when they are *I(1)*).

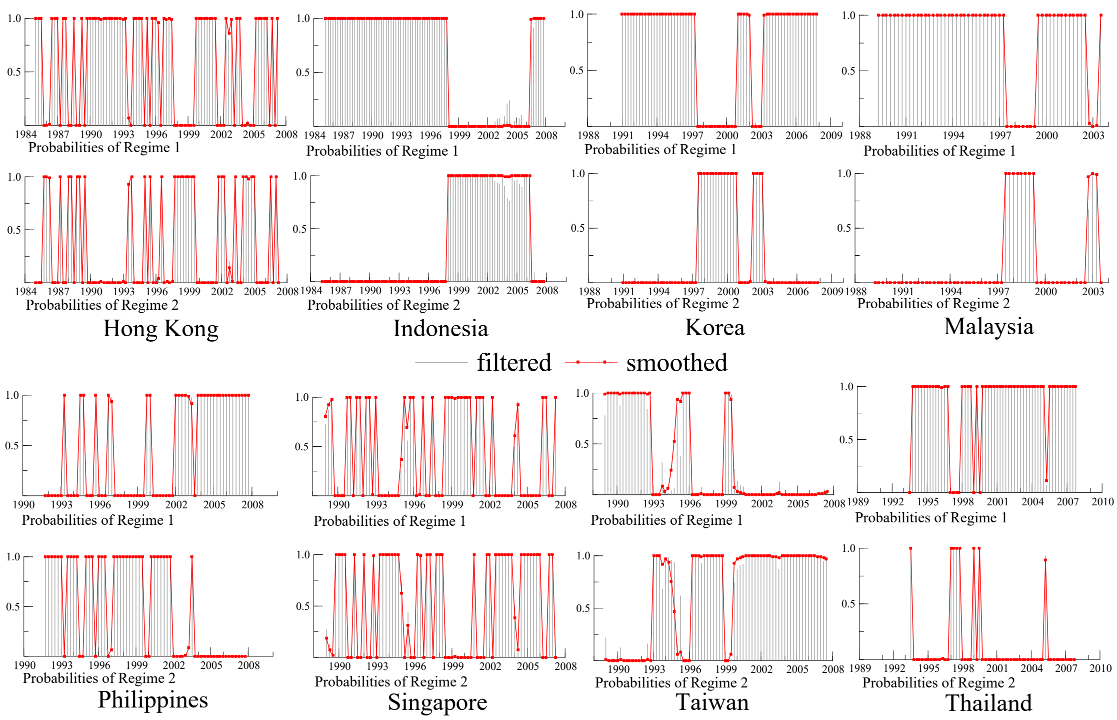


Figure A.2 – Filtered and smoothed probabilities of being in regime 1 and 2, as inferred by Baum-Lindgren-Hamilton-Kim filter and smoother in the MS-VAR model.

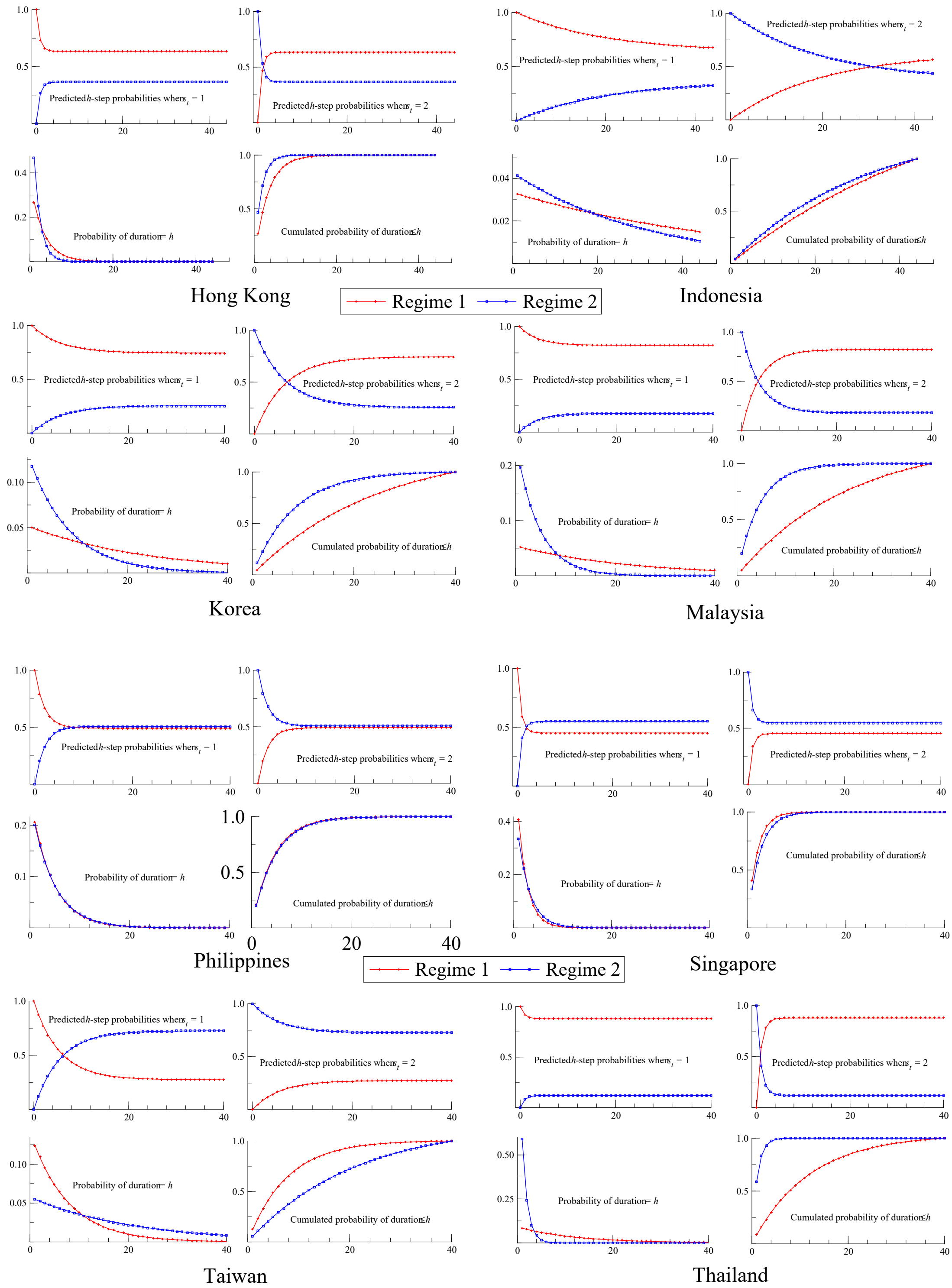


Figure A.3 – Dynamic properties of the MS-VAR model. The evolution of the predicted probabilities of being in regime 1 (up-left) and regime 2 (up-right), the probability of duration equal to *h* quarters (bottom-left) and the cumulative probability of duration equal or less than *h* quarters (bottom-right) are analyzed for each country.

Table A.2 - Johansen's test cannot reject cointegration for Taiwan and Thailand.

Johansen's Cointegration Test								
	p-r	r	Eig.Value	Trace	Trace*	Frac95	P-Value	P-Value*
Taiwan	2	0	0.326	40.579	33.166	30.775	0.003	0.026
	1	1	0.162	12.538	9.091	15.251	0.124	0.334
	p-r	r	Eig.Value	Trace	Trace*	Frac95	P-Value	P-Value*
Thailand	2	0	0.370	26.233	25.538	30.775	0.148	0.172
	1	1	0.024	1.317	1.259	15.251	0.997	0.997

(*): Small sample corrected Statistics.

Table A.3 – MS-VECM estimation procedure, as given by Krolzig (1997) and Krolzig & Toro (1999). Equations (A1) and (A1') are standard linear VECMs, y_t is a vector of *I(1)* variables forming a cointegrating relationship, and x_t is a vector of weakly exogenous stationary variables. In the first step both linear VECMs are estimated; the difference between the two is that (A1) has a constant which is restricted to the cointegrating relationship. In the second step, keeping the cointegrating relationship fixed, the model parameters are re-estimated including a Markov-switching intercept. The effects of this intercept will then have to be absorbed either by time-series mean μ^*_m or long-run equilibria means δ_m, so that each regime *m* is associated with an attractor (δ_m, μ^*_m). This is shown in equations (A2), (A2') , (A3) and (A3').

	Taiwan	*Thailand*
Step 1	$\Delta y_t = \alpha\gamma_0 + \alpha\beta' y_{t-1} + \sum_{i=1}^{p-1}\Gamma_i \Delta y_{t-i} + \sum_{k=1}^{p-1} A_i[x_{t-1}] + u_t,$ $y_t = \begin{bmatrix} I \\ E \end{bmatrix}, \quad x_t = \begin{bmatrix} D(U) \\ D(\ln R) \end{bmatrix},$ (A1)	$\Delta y_t = \alpha\beta' y_{t-1} + \sum_{i=1}^{p-1}\Gamma_i \Delta y_{t-i} + \sum_{k=1}^{p-1} A_i[x_{t-1}] + u_t,$ $y_t = \begin{bmatrix} I \\ E \end{bmatrix}, \quad x_t = \begin{bmatrix} D(ED) \\ D(\ln GDP) \end{bmatrix},$ (A1')
Step 2	$\Delta y_t - \mu_m = \alpha[\beta' y_{t-1} - \gamma_0 - \delta_m] + \sum_{i=1}^{p-1}\Gamma_i(\Delta y_{t-i} - \mu_m) + \sum_{k=1}^{p-1} A_i[x_{t-1}] + u_t,$ (A2)	$\Delta y_t - \mu_m = \alpha[\beta' y_{t-1} - \delta_m] + \sum_{i=1}^{p-1}\Gamma_i(\Delta y_{t-i} - \mu_m) + \sum_{k=1}^{p-1} A_i[x_{t-1}] + u_t,$ (A2')
MS Intercept	$vec[-\alpha\delta_m + D(1)\beta\perp\mu^*_m] = \begin{bmatrix} -\alpha\delta_1 + D(1)\beta\perp\mu^*_{\Delta I1} \\ -\alpha\delta_1 + D(1)\beta\perp\mu^*_{\Delta E1} \\ -\alpha\delta_2 + D(1)\beta\perp\mu^*_{\Delta I2} \\ -\alpha\delta_2 + D(1)\beta\perp\mu^*_{\Delta E2} \end{bmatrix} = \begin{bmatrix} 0.1604 \\ -13.705 \\ -0.1735 \\ 9.104 \end{bmatrix},$ (A.3)	$vec[-\alpha\delta_m + D(1)\beta\perp\mu^*_m] = \begin{bmatrix} -\alpha\delta_1 + D(1)\beta\perp\mu^*_{\Delta I1} \\ -\alpha\delta_1 + D(1)\beta\perp\mu^*_{\Delta E1} \\ -\alpha\delta_2 + D(1)\beta\perp\mu^*_{\Delta I2} \\ -\alpha\delta_2 + D(1)\beta\perp\mu^*_{\Delta E2} \end{bmatrix} = \begin{bmatrix} 0.1604 \\ -13.705 \\ -0.1735 \\ 9.104 \end{bmatrix},$ (A3')
Properties	Lags = 4 Coint. Relationships = 1 Regimes = 2 Probability matrix $P = \begin{bmatrix} 0.7697 & 0.2303 \\ 0.2846 & 0.7154 \end{bmatrix}$	Lags = 4 Coint. Relationships = 1 Regimes = 2 Probability Matrix $P = \begin{bmatrix} 0.9090 & 0.0910 \\ 0.5564 & 0.4436 \end{bmatrix}$

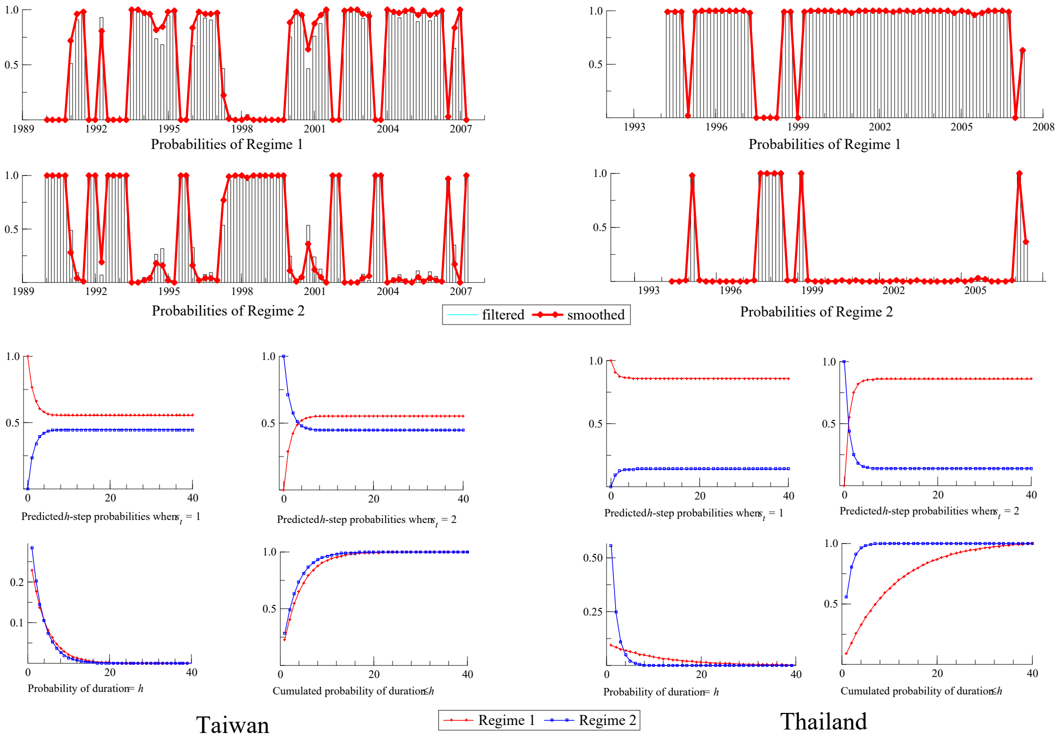


Figure A.4 – Probabilities of being in regime 1 and 2, and dynamic properties of the MS-VECM.