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Can the persistence of a currency crisis be explained by fundamentals? Markov switching models for exchange market pressure

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Abstract

This paper investigates the contribution of fundamentals to the persistence of currency crises by identifying the determinants of high volatility in the exchange market pressure index (*empi*) for some new EU member states. The Markov switching model is utilised to identify the high volatility of *empi,* and a linear regression analysis is conducted to find the sources of the transition probability of the high volatility regime. The evidence does not seem to provide strong support for macroeconomic fundamentals, whereas it highlights the adverse movement of interest rates as the major determinant of the persistence of the currency crisis.

Keywords: Exchange market pressure; Markov switching model; Currency crisis; New EU member states.

JEL Classification: F3, 011

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1. Introduction

An index of speculative pressure known as the exchange market pressure index (*empi*) was advocated by Eichengreen et al. (1996), where currency crisis episodes are identified by the changes in the three components of nominal exchange rates, international reserves and interest rates[1]. A substantial body of empirical literature has followed by constructing an 'early warning system' to predict a currency crisis based on *empi* (e.g. Kaminsky et al. 1998, Berg et al. 2000, Cerra and Saxena 2002, Edison 2003 and Kamin et al. 2007). In all, identifying leading indicators for currency crisis episodes plays a crucial role in these empirical studies with indicators such as fundamentals, financial variables or fiscal indicators by setting a threshold. Some studies have stressed the contagion effect of financial crises, as observed from many crises of the 1990s (e.g. Glick and Rose 1999, Kaminsky and Reinhart 2000, and Fratzscher 2003).

In this paper, departing from the earlier literature, we investigate the driving forces behind the high volatility in *empi* by utilising the Markov switching model for the Czech Republic, Hungary, Poland, Slovakia and Slovenia over the sample period 1994 to 2006 by using the monthly data[2]. The purpose of this paper is not to predict the early warning for currency crisis, but to establish the relative importance of different forces driving the increasing volatility of *empi*. Note that Mody and Taylor (2007) investigated the determinants of *empi* by taking account of common regional factors for the Asian financial crisis region, but their work is limited to be the *level* of *empi*.

The methodology applied in this paper is based on two stages. In the first stage, the two-state Markov switching model is utilised to identify low and high volatility regimes of *empi.* After the pioneering work of Hamilton (1989), the Markov switching models have been used extensively in modelling non-linear financial time series due to their greater power to distinguish different levels of volatility[3]. In recent years, it has also been applied to the

currency crisis analysis, see, for example, Jeanne and Masson (2000), Cerra and Saxena (2002), Soledad and Peria (2002), Fratzscher (2003) and Abiad (2003). The advantage of the use of the Markov model is the ability to detect the turning points between tranquil and speculative attack periods that are indicated by low and high regimes of volatility in *empi*, respectively. It is argued that a discrete measure of crises in probit models, which are frequently employed for the analysis of currency crises, leads to a loss of information on the scale of speculative pressure, as it excludes incidents below the arbitrary threshold value. This is a cause of sample bias, since the selection of only high values of *empi* as the dependent variable in the probit models may reduce the anticipated crises, which may arise from fluctuations at the lower level (Flood and Marion 1998). With Markov switching models (MSM), although the regime shift is not directly observable, probabilistic inferences can be drawn from the behaviour of observable series with no need for a priori dating of crisis episodes. This means that the identification and characterization of crisis periods are part of the models' output, which can be estimated simultaneously with the crisis forecast probabilities in a maximum likelihood framework. Such methodology could, therefore, avoid the pitfalls associated with the previous dating procedure[4].

In the second stage, a linear regression analysis is conducted with the probability values of the high volatility or high pressure period derived from MSM as a dependent variable. The dependent variable is regressed linearly upon a set of economic and financial indicators, in order to explore the potential determinants that govern the high pressure period, or sustain the crisis period. It is argued that currency crises are usually preceded by a broad range of economic problems, for example, Kaminsky et al. (1998) identified various indicators as signalling devices to a currency crisis. Hence, a wider set of variables are considered including the macroeconomic fundamentals and the determinants relating to the characteristics of financial sector soundness.

Note that the time-varying transition probability (TVTP) of the Markov model is, perhaps, more robust, since the indicators can enter both the level of *empi* and the transition probabilities simultaneously, thereby there is no loss of information. However, such a model strategy may be impractical in the current study. With a large set of indicator variables specified, the major limitation is the difficulty in detecting the significant coefficients and also in obtaining convergence. For example, Cerra and Saxena (2002) analyse Indonesia's currency crisis by applying the TVTP model. Although, a relatively large set of variables are considered in Cerra and Saxena's study, in fact, the variables entered into TVTP include only *empi* for Thailand and Korea, in order to test the contagion effect from the neighbouring countries. Abiad (2003) also used TVTP for the Asian crisis episode during the period 1972-1999, but found it difficult to obtain significant coefficients on fundamentals[5]. Peria (2002) investigates the speculative attacks on the European Monetary System using the pooled data for seven monetary union member states over the sample period 1979-1993, with the transition probability being a logistic function of the six fundamental variables. In Peria (2002), most of the fundamentals fail to reach a standard significance level.

There are a number of reasons to apply this study to these transition economies. Firstly, since the transition process from command to market economies took place in the early 1990s, these economies have experienced varying exchange rate systems. In the earlier transition period, a fixed regime was common, and as the transition process progressed, managed flexible exchange rates or a widening of the bands were frequently introduced. Meanwhile, economic structural reforms were undertaken including a massive privatisation and market opening policy. With the unsettling of exchange rate systems and sizable structural changes to the economy, these economies have continued to be exposed to vulnerability to external shocks. Secondly, it is noted that currency crises tend to coexist with banking crises (Kaminsky and Reinhard 1996). This is particularly relevant for the transition economies with the frailty of their banking sectors. At the start of the transition period,

independent commercial banks were created from a former monobank system, and the newly established banks had, in effect, little capability for appraising projects. Consequently, the banking sector was prone to the accumulation of non-performing loans (NPL) leading to banking crises[6]. Moreover, in emerging economies, government and firms tend to rely on foreign currency denominated debt, hence exchange rate changes can have a significant impact on debtors' balance sheets or the profitability of banks (Amato and Gerlach 2002). Hence, stable exchange rates are one of the major factors which prevent banking crises. Given the current banking crisis, the study has never been more timely. Thirdly, it is associated with joining the European Monetary Union (EMU) for these new member countries. Joining the euro was subject to the participation in the ERM II as a pre-requisite under the Maastricht criteria, and the stability of foreign exchange markets is deemed to be a necessary condition. Slovenia joined ERM II in 2004 moving away from a managed floating system, and adopted the euro in 2007. The inclusion of Slovenia would provide a useful insight into joining the single currency for the new non-euro EU countries. With these considerations, it is hoped that this study is contributory to policy makers by delivering policy options concerning a course of actions to stabilise their foreign exchange markets and safeguard the value of their currency.

We find that our empirical results do not seem to provide a strong support for macroeconomic fundamentals, whereas it highlights the adverse movement of interest rates as the major determinant of the persistence of a currency crisis.

This paper is organised in the following manner. Section 2 specifies the index of exchange market pressure and the two states Markov-switching model with fixed transition probabilities. In Section 3, the potential determinants of high volatility in exchange market pressure are described, and also the data for estimation are spelled out. In Section 4 estimation results are presented. Section 5 concludes.

2 Exchange market pressure index and Markov switching model

The exchange market pressure index (*empi*) for a country *i* at time *t* can be constructed as:

$$empi_{it} = \alpha \frac{\Delta e_{it}}{e_{it}} - \beta \frac{\Delta r_{it}}{r_{it}} + \gamma \Delta i_{it} \qquad (1)$$

where e_{it}, r_{it} and i_{it} denote, respectively, the nominal exchange rate (domestic price of foreign currency), level of foreign exchange reserves and short-term interest rates. Δ denotes the first-difference operator. The weights α, β and γ are chosen such that each of the three components on the right-hand side of equation (1) has a standard deviation of unity, which is to preclude any one of them from dominating the index. Note that changes in exchange rates and interest rates enter with a positive weight and changes in reserves have a negative weight, so that deprecation of exchange rates, a sharp increase in interest rates, and a decline in reserves raise the index of exchange market pressure.

An intense increase in speculative pressure on a currency is an indication of currency crisis, and a high *empi* implies the high pressure imposed on the currency. Equation (1) suggests that if there is an attack on the currency, the exchange rate would depreciate, interest rates are raised, or foreign reserves are withdrawn due to the central banks' intervention to prevent the attack.

We model the currency crisis by assuming that the market pressure indicator computed in equation (1) follows a Markov process with a fixed transition probability. Suppose a discrete random variable S_t takes on two possible values [$S_t = (0,1)$], where the value $S_t = 0$ indicates a period of low pressure for devaluation, and $S_t = 1$ denotes a period of high devaluation pressure[7]. *empi* , which is conditional on the value of S_t is given by

$$empi_t = \alpha_0 (1 - S_t) + \alpha_1 S_t + \sigma(S_t)\varepsilon_t \qquad (2)$$

where ε_t is an *i.i.d N(0, 1)* variable. S_t is an unobserved indicator variable that evolves according to a first-order Markov-switching process as in Hamilton (1989),

$$P\left[S_t = 0 \middle| S_{t-1} = 0\right] = p_0$$

$$P\left[S_t = 1 \middle| S_{t-1} = 1\right] = p_1$$

$$0 < p_0 < 1, \quad 0 < p_1 < 1$$

where p_0 and p_1 are fixed transition probabilities of being in tranquil and high pressure (crisis) periods, respectively. Since S_t is unobservable, the unknown parameters of the model can be estimated using the non-linear filter proposed by Hamilton (1989). Further, with Hamilton's algorithm we can obtain the filtered probabilities, i.e. the probabilities of being in state S, which is conditional upon the information available at time *t*,

$$\Pr_t = \Pr\left(S_t = S \middle| empi_t, \ldots, empi_1\right) \qquad (3)$$

These provide information about the state, in which $empi_t$ is most likely to be at every point of the observations in the sample.

3. Determinants of high volatility in exchange market pressure and data for estimation

In Kaminsky et.al (1998) and Edison (2003), vulnerability to crisis is signalled when 'indicator variables' deviate from their behaviour during non-crisis periods. We take such indicator variables as the driving force to a high volatility regime in *empi* in this paper. The indicator variables are chosen based on the following theoretical aspects.

It is argued that crises were caused by economic fundamentals, such as excessive expansionary monetary and fiscal policies, leading to a substantial loss of foreign reserves under a fixed exchange rate regime (Krugman 1979). Similarly, domestic credit expansion above the growth rate of money demand is likely to deplete international reserves. With the loss of reserves, yet under the circumstances where the authorities adhere to an exchange rate parity, domestic interest rates have to increase and stay to be at a high level. The adverse consequence is a fall in the level of output and employment due to a higher level of borrowing

costs. The detrimental effect of expansionary policy may also be translated into the trade balance and exchange rates. An increase in demand for traded goods worsens the terms of trade, whereas a higher demand for non-traded goods increases the relative prices of these goods and we may observe a real appreciation of exchange rates. It is known that a real appreciation and deterioration of the trade balance are shown to be prone to speculative attacks.

Under the fixed rate system, domestic interest rates move in line with foreign interest rates, though to a lesser degree in the case of a crawling peg system. When domestic interest rates are raised more than an increase in foreign interest rates, for example, due to the depletion of foreign reserves, such a situation is a cause of high volatility. However, on the other hand, if foreign interest rates exceed a tolerable level, the cost of maintaining the exchange rate may outweigh the benefits, since the high domestic interest rates dampen both investment and output. In these circumstances, a volatile state may also be inevitable. Interest rates are therefore compelling candidates as determinants of high volatility.

The banking crises can be reflected in such indicators as stock prices in the banking sector, the proportion of non-performing assets, the level of central banks' credit to banks, a decline in deposits and the spread between lending and deposit rates.

[Table 1 around here]

With the above considerations, and also with data availability on a monthly basis, we explore a broad range of 18 dependent variables as the determinants of high volatility in *empi* for the Czech Republic, Hungary, Poland, Slovakia and Slovenia over the sample period 1994:01 to 2006:12. The variables can be classified into five groups of current account indicators, capital account indicators, real sector indicators, financial indicators and also external indicators[8]. Data are listed in Table 1 with the abbreviation of each variable and the predicted signs in brackets. The (+) implies that an increase in variables is associated with a

high volatility, whilst the (-) indicates that a decrease is related to the high volatility period. Data sources are found in Appendix.

4. Empirical results

4.1 Markov switching model

[Table 2 and Figure 1 around here]

Table 2 shows the estimates from MSM for the five countries. The Davies (1987) upper bound test is adopted for the null of linearity[9]. The results show that the linearity of *empi* can be rejected for all cases, confirming the nonlinearity. The volatility, indicated by the estimates of σ in both states are statistically highly significant at above 1 percent level, and the magnitude of the coefficient in regime 1 is much larger than that in regime 0, ranging from 2.05 times in Poland to 13.22 times in Slovakia. These results provide the crucial statistical evidence that there exist two volatility regimes of tranquil and crisis periods in the series of *empi*, though the two-state means are not so significant. State 0 can be identified as a low-mean, low-volatility regime, whereas state 1 is a high-mean, high-volatility regime.

In Figure 1, the level of *empi* specified in equation (1) is plotted at the top of each graph with the scale on the right hand side, together with the probability of the high volatility regime of *empi* derived from MSM at the bottom with the scale on the left hand side for comparison. The charts show that large fluctuations in *empi* appear to correspond well with the high probability of the volatile regime. Hence, when a country is under a higher pressure of depreciation with a large positive value of *empi,* the foreign exchange market is likely to be in a high volatility regime.

Each country seems to have experienced a different degree of stress at a different period, yet, there are some common features apparent in Figure 1. During the early period in 1994-1995, almost all of the countries demonstrated a high volatility, suggesting that their currencies were under pressure of a speculative attack. The transition process from the

planned to market economies in the early sample period may have exerted a high tension in the foreign exchange markets. During the Asian and Russian crises in 1997-98, volatile markets are also evident, yet it is not certain whether this is solely due to contingent effects, since at the same time these countries had their own currency crisis and/or the changes in the exchange rate systems (as described in the subsequent paragraph below). It is noticeable that a short-lived high volatility is exhibited in 2002 for the Czech republic, Hungary and Slovakia, implying that entering the EU may have caused some degree of concern about speculative attack.

The introduction of a managed or full floating exchange rate regime broadly corresponds with a high volatility regime of *empi,* especially for the Czech Republic and Slovakia, who adopted the floating system following the currency crisis of 1997 and 1998 respectively[10]. At the time of the currency crisis, *empi* peaked with almost 100% probability of staying in a high volatility regime[11]. The only exception is for Hungary, where it had a low volatility when a floating system was adopted in 2001. However, when Hungary and also Poland widened the band to as large as circa 15% in 1998, high volatility is evident.

Slovenia opted for ERM II in 2004 from the managed floating system, and joined the euro in January 2007. It is apparent that the low probability of high volatility is sustained for Slovenia from around 2000 onward leading to its joining the monetary union in 2004.

4.2 Linear regression results

[Table 3 around here]

A regression analysis is conducted, as shown in Table 3 with the transition probability of the high volatility regime derived from MSM as the dependent variable. This investigates the variables governing the persistence of the crisis. We take lagged-once regressors with the assumption that the transition probability at *t* is formed based on information contained in indicators at *t-1*[12]. The variables marked with * have statistically significant coefficients at

the 10% or higher level with the correct sign. In general, Hungary has a relatively better empirical performance with more significant coefficients.

Whilst a number of common findings are observed amongst these countries, the performance of each indicator widely varies from country to country. In this respect, the assumption of parameter equality across countries based on a panel of countries in the currency crisis literature (Peria 2000 and Fiess and Shanker 2009) may result in poor predictive performance. The results bear a number of determinants which should merit more scrutiny for individual countries. For example, deviations of the real exchange rate from the trend (*reex_w*) should be monitored in Hungary and Slovenia. The foreign exchange reserves (*fr*) may be critical indicators to the persistence of a volatile foreign exchange market in Poland and Slovakia. Expansionary monetary policy, exceeding the growth rate of foreign reserves (*m2/fr*), is likely to be the cause of the high volatility regime in Slovakia. The contraction of the economy *(ip*) and the stock market (*stock*) seem to be responsible for the instability in the Czech Republic. A growth in domestic credit is also a concern in Hungary.

One of the common findings is that a high volatility regime appears to be driven by variables that are related to the adverse movement of interest rates, i.e. *lr/dr, rdr* and *rid_w*. In each country, at least one of the coefficients is significant (in the case of Hungary and Slovakia, all three coefficients are significant). The finding of a robust link between interest rates and the high volatility regime accords with the literature of currency crises: For example, an increase in domestic interest rates raises financing costs for the government. When it is perceived by agents that the government is concerned with the fiscal consequences of a higher interest rate due to a high level of public debt, this may be the cause of currency crisis with *empi* being in a high volatility state. Also, if financial stability is one of the objectives set by government, higher interest rates are likely to increase the default rate, weakening the banking system. The authorities may, then, choose to devalue by lowering interest rates, when the cost of bailing out the banking system is high (Velasco 1987 and

Calvo 1995). When such a policy action is expected by speculators, high pressure on foreign exchange markets may emerge[13].

Other general findings include the following. Contrary to expectations, the current account balance (import and export) is not much supported as a useful indicator of crises. This is not exclusive to our study, since much of the literature also finds little role of the current account balance. It is likely that information embedded in the evolution of imports and exports may already have been reflected in the behaviour of real exchange rates (Kaminsky et al. 1998)[14]. Note, however, that the real overvaluation indicator is only significant in Hungary and Slovenia in the current study. The variables associated with international reserves did not fare well in some of these countries, despite the fact that the decline in foreign reserves is traditionally supported as the cause of a currency crisis. Overall, the real sector and external indicators also have little predictive power during the currency crises. We leave the discussion of the insignificant effect of these key macroeconomic variables to the conclusion.

5. Conclusion

The main objective of this paper is to investigate the determinants of the high volatility regime in exchange market pressure that is associated with a currency crisis in some new EU member states. The model developed in this paper allows the transition probability of high volatility periods to be a function of various determinants. We assumed that macroeconomic fundamentals and financial variables affect the probability of regime transition.

The overall result suggests that variables related to interest rates have been shown to be contributions to the persistence of high volatility regimes in all cases, whereas the empirical evidence points less to balance of payment indicators and real sector variables as determinants. The latter is contrasted with the study on the warning system, where a broad variety of indicators is found, and currency crises seem to be preceded by multiple economic

variables[15]. In this respect, in terms of the predictability, macroeconomic fundamentals may indeed be useful indicators for triggering a currency crisis, yet they may no longer be the robust determinants during the crises period.

The weak effect of the macroeconomic fundamentals appears to support the self-fulfilling nature of speculative attacks, for example, Obstfeld (1996) showed that currency crises can happen even when the level of foreign reserves is sound. Obstfeld (1994) emphasizes endogenous economic policies and agents' expectations[16]: Policymakers respond to changes in the economy, and agents' expectations are formed based on such a relationship, and these expectations, in turn, affect some variables to which policymakers again react. Henceforth, this circularity gives rise to self-fulfilling crises, and is said to generate multiple equilibria, where the economy moves from one equilibrium to another without a significant change in the fundamentals, but with changes to agents' expectations (Kaminsky et al. 1998). An implication of self-fulfilling crises is that these limit the investigation of attempts to find a defined relationship between fundamentals and crises, since a crisis may be persistent without a prior significant change in fundamentals. Although it is not clear that such expectations are subsumed in the movement of interest rates in this paper, the significant effect of interest rate differentials or real deposit rates on the high volatility in *empi* may serve to prove that this may be the case.

Appendix Data sources (1994:01 to 2006:12)

Variables	Source
Deposits	IFS line 24 (demand deposits) and 25 (time deposits)
Deposit rates	IFS line 60L, except for German and USA deposit rates which are retrieved from Datastream
Lending rates	IFS line 60P
CPI (inflation)	IFS line 64, except for the euro area CPI, which is retrieved from OECD Main Economic Indicator
Export	IFS line 70
Import	IFS line 71
Foreign exchange reserves	IFS line 1D
Domestic credit[1]	IFS line 32
Industrial production	IFS line 66
M2 (money and quasi money)	IFS line 35L
M1 (money)	IFS line 34
M0	Datastream Base money
Stock prices	IFS line 62
Exchange rates US$	IFS line RF, a number of domestic currency per US$
Exchange rates ECU/Euro	Datastream, a number of domestic currency per Euro
Short term interest rates	Datastream
Foreign liabilities	IFS line 16C
Base money	Datastream M0
GDP in US and Germany	IFS line 66 industrial production
Oil price	Datastream Crude oil

[1] To the extent that excessive credit to the public sector and also excessive central bank credit to banking sector may play the same role in currency crises, we use the data of 'domestic credit', which include claims on central government, private sector and financial institutions.

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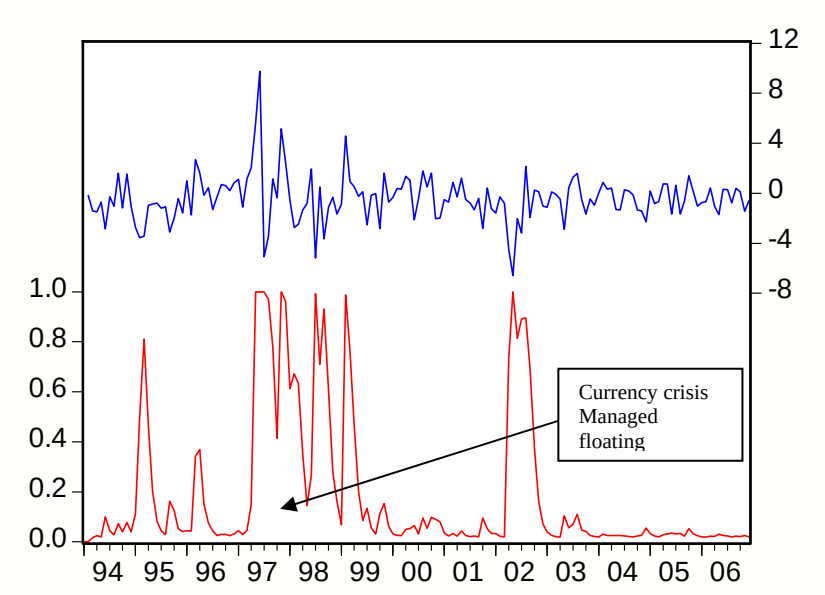
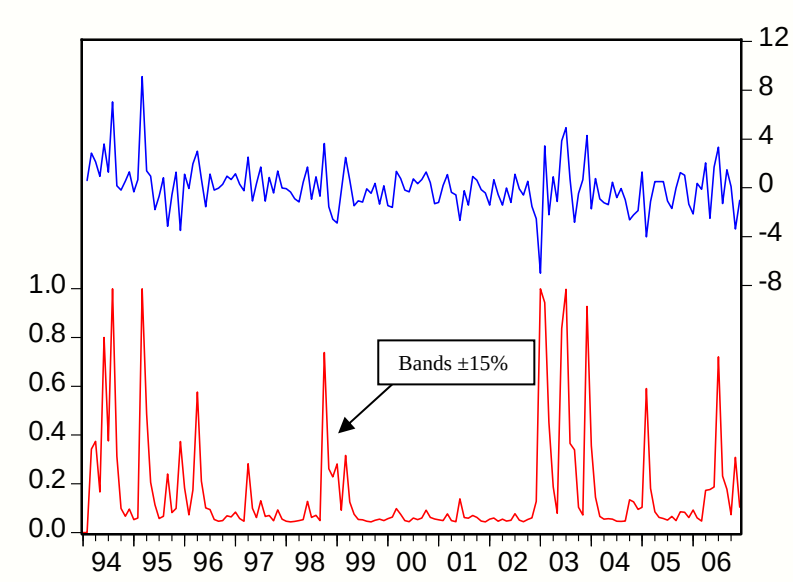
Figure 1 ***empi*** **(top plot) and probability of high volatility period based on MSM (bottom plot)**

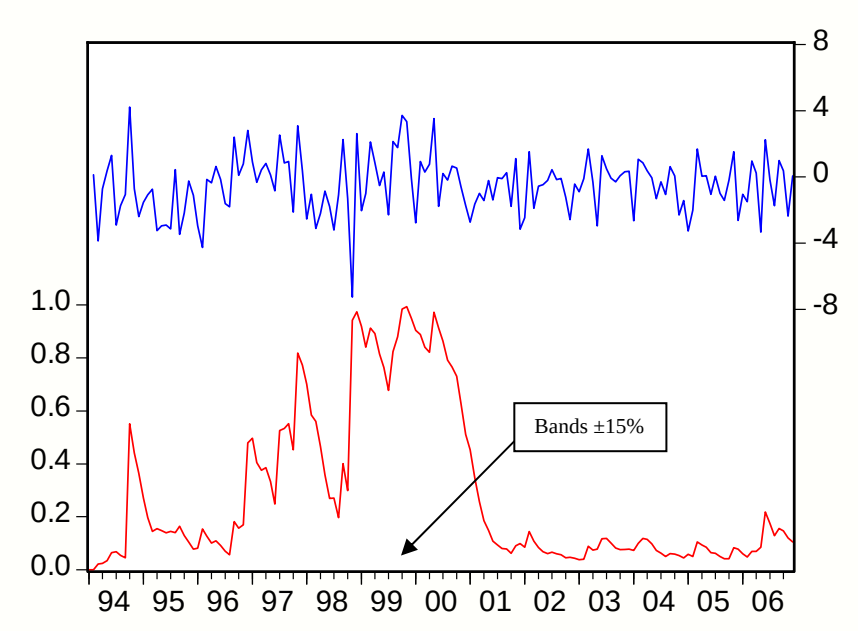
(a) Czech Republic



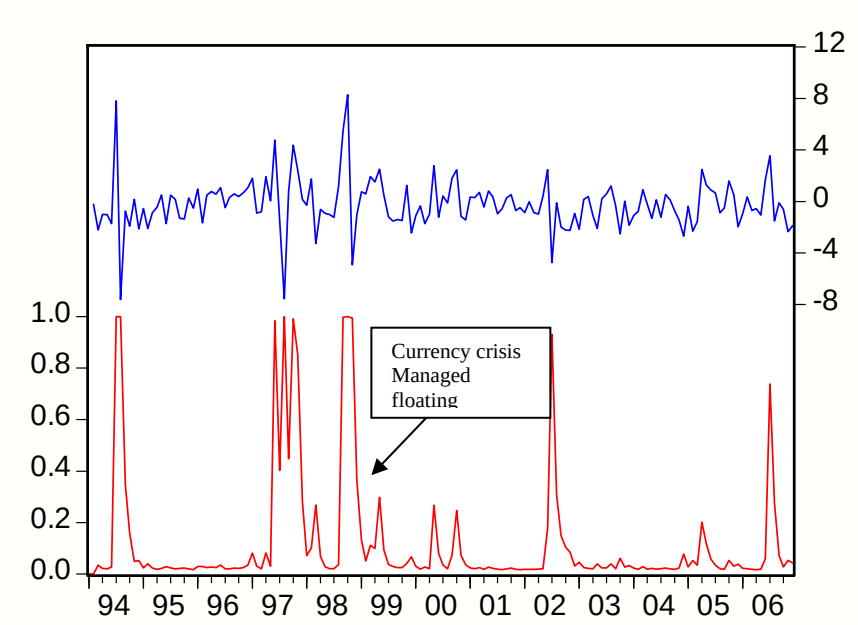
(b) Hungary



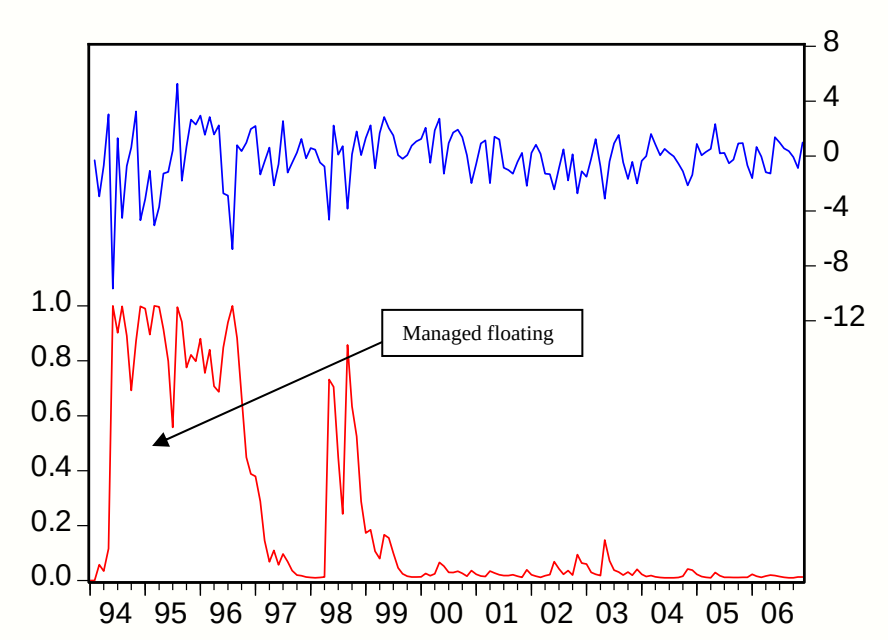
(c) Poland



(c) Slovakia



(e) Slovenia



Notes for Figure 1:

The exchange rate systems of the five new EU countries

Czech Rep.	1995	Bands widened from ±0.5% to ±7.5%
	1997 May	Managed floating
Hungary	1995 Mar.	Crawling peg with a band of ±2.5%
	1998 Feb.	Bands widened to ±15%
	2001 Oct.	Managed floating
Poland	1995 May	Bands widened from ±2.5% to ±7.5%
	1998 Feb.	Bands widened from ±7% to ±10%, to ±12.5% in October 1998 and to ±15% in 1999 March.
	2000 April	Independent Floating
Slovakia	1995	Bands widened to ±7%
	1998 Oct.	Managed floating
Slovenia	1993 to 2004	Managed floating
	2004 June	Joined the ERM II from managed floating
	2007 Jan	Joined the euro

Table 1 Economic and fundamental indicators with the predicted sign[1]

Indicators	Notations (expected sign)	Impact on crisis
Current account indicators		
Deviations of the real exchange rate from the trend[2]	*reex_w* (-)	A large misalignments (over-valuation or negative deviation) of the real exchange rate is linked to instability.
Imports and exports:	*imp* (+) *exp* (-)	A deterioration of the trade balance indicates an overvalued exchange rate leading to a lower export growth and increased import growth. A weak external sector is linked to instability.
Capital account indicators		
Foreign exchange reserves	*fr* (-)	Loss of foreign reserve is associated with instability.
M2/foreign exchange reserves	*m2/fr* (+)*	Expansionary monetary policy with a fall in foreign reserves are linked to instability.
Ratio of foreign liabilities to foreign exchange reserves	*fl/fr* (+)*	This measures foreign exchange exposure risks in the financial sector, since large capital inflows fuel a lending boom and it proxies the vulnerability of the economy to a sudden reversal of capital inflows. An increase in debt and a decline in foreign reserves are likely to cause high volatility.
Real sector indicators		
Industrial production	*ip* (-)	Boom (recession) period is linked to a tranquil (high volatility) period.
Stock prices	*stock* (-)	Some crises have been preceded by the bursting of an asset market bubble, so a sharp fall in asset price is linked to high volatility.
Financial indicators		
Multiplier (ratio of m2 to base money)	*m2/bm* (+)*	The ratio indicates the potential growth of credit.
Ratio of domestic credit to nominal GDP	*dc/ip* (+)*	A rapid expansion in credit signifies a growing strain in the economy, in particular to the banking sector.
Excess real M1 balances [4]	*exm1*(+)*	A loose monetary policy is linked to volatility.
Commercial bank deposits	*dep* (-)	A sharp decline of deposits indicate increased banking system fragility with an inadequate level of liquidity to respond to shocks.
Ratio of lending to deposit interest rates	*lr/dr* (+)*	A high lending rate reflects decline in the quality of loans, and leads to an increase in non-performing loans and default rate.
Real interest rates on deposits	*rdr* (+)*	A high real deposit rate may indicate a liquidity problem. In general, increased real interest rates suggest fending off a speculative attack.
The domestic and foreign real interest rate differential on deposits [3]	*rid_w* (+) or (-)	The widening of the real interest rate differential may lead to high volatility.
External indicators		
US and German output	*ip_us* (-) *ip_gm* (-)	A recession in large economies is associated with volatility.
Oil price	*oil* (+)	High oil prices are linked to volatility.

Note:

[1] The measure of percentage change is used, except for * marked variables, which are checked for stationarity. The * marked variables that failed to reject the non-stationary at the 5 percent significant level by the Augmented Dickey Fuller are considered as containing a unit root, and therefore are transformed into the first difference of the series in the linear regression. The unit root tests are available from the authors on request.

[2] The trend is based on the Hodrick-Prescott filter. The variable is a weighted average of US$ and ECU/Euro with 35% and 65% respectively.

[3] The foreign interest rate is a weighted average of US (35%) and Germany (65%).

[4] We estimated the demand for real money balance with the explanatory variables of GDP (proxied by industrial production), inflation and time trend, and took the difference between the actual and fitted values of the real money.

Table 2: Estimates from the two-state Markov switching model with the fixed transition probabilities

	Czech	Hungary	Poland	Slovakia	Slovenia
$\alpha 1$	-0.411 (-0.580)	1.180 (1.424)	-0.1001 (-0.331)	0.603 (0.557)	-0.668 (-1.064)
$\alpha 0$	-0.431 (-3.825)	-0.184 (-1.276)	-0.698 (-4.444)	-0.350 (-3.022)	0.057 (0.453)
$\sigma 1$	12.430 (3.533)	11.417 (2.613)	4.6279 (4.468)	20.373 (2.066)	10.555 (3.719)
$\sigma 0$	1.433 (6.501)	1.712 (4.675)	2.257 (6.066)	1.548 (6.513)	1.759 (6.210)
P1	0.854 (2.537)	0.542 (0.164)	0.967 (3.318)	0.658 (1.046)	0.946 (2.738)
P0	0.964 (4.211)	0.906 (2.615)	0.984 (4.290)	0.952 (6.293)	0.985 (5.625)
L'value	-292.49	-302.23	-302.11	-294.48	-301.11
L'value*	-318.67	-319.34	-307.27	-326.29	-322.14
LR	52.36 [0.000]	34.22 [0.000]	10.32 [0.065]	63.62 [0.000]	42.06 [0.000]

Note: * is the log likelihood value from the one-state model. t-statistics in parentheses. LR is the likelihood ratio test of one-state against two-state. The number in the square bracket is the Davies (1987) upper bound p-value.

Table 3 Regression analysis with the dependent variable of the transition probability in high volatility period derived from MSM model

	Czech	Hungary	Poland	Slovakia	Slovenia
Constant	-1.162	-0.620 *	1.525 *	-0.008	0.039
	(-1.298)	(-2.319)	(11.525)	(-0.183)	(1.239)
Current account indicators					
reex_w	0.619	-1.881*	0.404	0.703	-4.985 *
-	(0.851)	(-2.386)	(0.746)	(1.059)	(-5.825)
imp	-0.158	0.380	-0.257	-0.230	-0.227
+	(-0.489)	(1.487)	(-0.710)	(-1.024)	(-0.929)
exp	0.499	0.178	0.003	0.176	0.144
-	(1.195)	(0.664)	(0.009)	(0.522)	(0.540)
Capital account indicators					
fr	0.382	0.569	-1.485 *	-0.268 *	-0.325
-	(0.659)	(0.693)	(-3.092)	(-1.735)	(-0.374)
m2/fr	-0.243	0.383	-0.752	0.073 *	-0.635
+	(-1.570)	(0.504)	(-9.839)	(1.821)	(-0.714)
fl/fr	0.008	-0.021	0.106*	-0.008	0.004
+	(0.367)	(-0.315)	(4.488)	(-0.203)	(0.227)
Real sector indicators					
ip	-2.031 *	2.908	-1.572	-1.350	-1.659
-	(-1.644)	(2.563)	(-1.183)	(-1.588)	(-1.163)
stock	-0.586 *	-0.195	-0.085	-0.300	-0.304
-	(-1.956)	(-1.143)	(-0.424)	(-1.867)	(-1.201)
Financial indicators					
m2/bm	3.673 *	-0.876	-0.003	-0.834	0.004
+	(2.682)	(-2.316)	(-0.012)	(-1.083)	(0.014)
dc/ip	-1.632	3.409 *	-1.316	-0.558	-0.927
+	(-1.413)	(3.129)	(-1.074)	(-1.078)	(-0.783)
exm1	-0.102	1.254 *	-0.489	-0.618	0.489 *
+	(-0.294)	(3.634)	(-0.839)	(-1.190)	(3.764)
dep	-3.966 *	-0.946	1.934	0.952	1.896
-	(-2.220)	(-0.726)	(1.598)	(1.078)	(1.271)
lr/dr	-0.013	0.518 *	0.125	0.209 *	0.412 *
+	(-0.047)	(2.652)	(0.552)	(1.761)	(2.309)
rdr	0.018	0.073 *	0.075 *	0.095*	0.050 *
+	(0.240)	(2.033)	(6.460)	(3.294)	(4.619)
rid_w	0.069 *	0.008 *	-0.075*	0.015 *	-0.015
+ -	(5.985)	(2.461)	(-5.902)	(2.932)	(-1.251)
External indicators					
ip_gm	-0.165	0.013	-0.100	0.459	-0.127
-	(-0.360)	(0.037)	(-0.304)	(1.254)	(-0.258)
ip_us	1.327	0.749	-0.093	1.372	0.728
-	(1.033)	(0.937)	(-0.105)	(1.423)	(0.813)
oil	-0.001	0.504 *	0.117	0.060	0.058
+	(-0.003)	(2.470)	(0.541)	(0.249)	(0.237)
F-test for overall significance [Prob. Value]	3.386 [0.000]	4.441 [0.000]	12.485 [0.000]	3.165 [0.000]	14.320 [0.000]

t-ratios are in bracket. The predicted sign is attached to each explanatory variable.

* The coefficients are significant at least at the level of 10% with the correct sign.

Endnotes

[1] Most of the previous studies exclusively focused on devaluation episodes. The exchange rate market pressure is a broader definition of crisis, which includes not only devaluations, but also episodes of unsuccessful speculative attacks. When a currency is under attack, the central bank can intervene by either an increase in domestic interest rates or a substantial loss of foreign reserves to avert the attack (Kaminsky et al. 1998). Speculative pressures may not be addressed by merely looking at the data of nominal exchange rates.

[2] We concentrate on the five large 'first' waves of new EU member states in the Central Eastern Europe region due to data availability.

[3] For example, Ramchand and Susmel (1998), Hamilton and Susmel (1994), Ang and Bekaert (2002), Morana and Beltratti (2002), Billio and Pelizzon (2003) and Moore and Wang (2007) apply the Markove model to the volatility of stock returns; Gray (1996) and Garcia and Perron (1996) to interest rates; Engle and Hamilton (1990) and Dewachter (2001) to foreign currencies; others such as Kim and Nelson (1999) to the behaviour of business cycles.

[4] The value of a threshold is determined, and any value of the index that exceeds the threshold value is classified as high pressure. This is referred to as the dating procedure.

[5] Note that in Abiad (2003), the series under investigation is the nominal exchange rates. Abiad finds that the coefficients on the indicators in TVTP model are all correctly signed, but are mostly insignificant.

[6] For example, the available data show that a relatively high proportion of NPL at 29.3% of GDP is recorded for the Czech Republic in 2000 and 18.6% for Poland in 2001 (World Development Indicator).

[7] It is assumed that when *empi* is in a low (high) volatility regime, the pressure for devaluation is low (high).

[8] Contagion effects are commonly found in currency crises (e.g. Gerlach and Smets 1994, Cerra and Sacena 2002). For example, devaluation of exchange rates in one country may trigger devaluation in neighbouring countries in order to maintain price competitiveness. Contagion effects may also arise due to investors' herding behaviour, paying little heed to countries' economic fundamentals (Calvo and Reinhard 1996, and Eichengreen et al. 1996). Political variables may also affect the volatility of *empi* (see Kaminsky et al 1998 and Cerra and Saxena 2002). In this paper, the effect of exchange market pressure in neighbouring countries is found to be insignificant in all cases, and also there is an inadequate data availability for political variables on a monthly basis. We do not pursue these strands.

[9] Davies's (1987) test is based on an adjustment to the Likelihood Ratio test statistic, and provides an upper bound for the correct probability value. The details of this test are found in Mills and Wang (2003).

[10] With a worsening trade deficit and an economic slowdown, the Czech koruna reached a ten month low against its currency basket in April 1997, and in May 1997, the target band was abandoned and the koruna depreciated almost immediately by around 10%.

[11] The probability of being in a high volatility regime can, therefore, be interpreted as having a 'currency crisis'.

[12] This is consistent with time varying transition probability model, where a vector of lagged indicators makes entry to the Markov model specification.

[13] Moreover, the expectation of a collapse, in turn, leads to higher interest rates, which may force the government to abandon parity, out of concern for the increased cost of servicing public debt. This further increases the probability of a banking crisis and the associated fiscal costs of a bailout (Obstfeld 1996).

[14] Frankel and Rose (1996) find that the overvaluation of real exchange rates increases the probability of a currency crash using panel annual data for 105 countries from 1971 to 1992.

[15] For example, Kaminsky et al. (1998) and Goldstein et al. (2000) utilised the signal extraction approach, and they find that the overwhelming majority of crises have numerous weak economic fundamentals at their core, including a slowdown in economic activity, overvalued exchange rates, reserve loss and a high ratio of broad money to international reserves for twenty developed and emerging economies using monthly data from 1970 to 1997.

[16] For example, refer back Footnote 14 in Section 4 in this paper.