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Can the Persistence of Currency Crises be Explained by the Indicators of Fundamentals?: Markov Switching Models for Exchange Market Pressure[1]

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Abstract: *In this paper, we, innovatively, apply the Markov switching model to exchange market pressure to identify the probability of staying in a high volatility regime, which can be interpreted as a persistence of the crisis. We, then, conduct a linear analysis to explore the determinants of the persistence by specifying a wide range of fundamentals. By applying this approach to some new EU member states, we find that the empirical results do not seem to provide a consistent, robust support for the fundamentals as determinants. The evidence highlights the self-fulfilling nature of speculative pressure.*

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

JEL Classification: *F3, 011*

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[2]. 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 play a crucial role in these empirical studies with indicators such as macroeconomics variables, financial variables or monetary and fiscal indicators by setting a threshold. Some studies have stressed the contagion effect of financial crises, as seen from many crises of the 1990s (e.g. Glick and Rose 1999, Kaminsky and Reinhart 2000, and Fratzscher 2003).

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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 with the monthly data[3]. The purpose of this paper is not to predict the early warning systems for currency crisis, but to establish the relative importance of different forces driving an increasing volatility of *empi*. Note that Mody and Taylor (2007) investigated the determinants of the *empi* by taking account of common regional factors for the Asian financial crisis region, but their work is on the *level* of *empi*. 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). Hence the volatile movement of *empi* is almost inevitable during the period of speculative pressure, which is indicative of a currency crisis. In this respect, a high state of volatility, rather than stability, even at a high level, in *empi* may be more of a concern for policy makers.

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 its greater power to distinguish different levels of volatility[4]. The advantage of using Markov switching model (MSM) is the ability of detecting 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 in a standard approach, a discrete measure of crises in the binary models 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 logit or probit models may reduce the anticipated crises, which may arise from fluctuations at the lower level (Flood and Marion 1998). With MSM, although the regime shift is not directly observable, the probabilistic inferences can be drawn from the behaviour of observable series with no need of a priori dating of crisis episodes. This means that the identification and characterization of crisis period 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[5]. In the second stage, following Fiess and Shankar (2009) a linear regression analysis is conducted with the probability values of the high volatility period derived from MSM as the dependent variable. The dependent variable is regressed linearly upon a set of economic and financial indicators as potential determinants, in order to explore the variables that govern the high volatility 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 currency crisis.

Hence, a wider set of variables are considered including the macroeconomic variables and the determinants relating to the characteristics of capital flows and to financial sector soundness[6].

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, the fixed regime was common, and as the transition process progressed, managed flexible exchange rates or widening the bands were frequently introduced. Meanwhile, the economic structural reforms were undertaken including the massive privatisation and market opening policy. With unsettling exchange rate systems and sizable structural changes on 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 the banking sector. 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 of appraising projects. Consequently, banking sector is prone to accumulate the non-performing loans (NPL) leading to banking crises[7]. Moreover, in emerging economies, government and firms tend to rely on foreign currency denominated debt, hence the exchange rate changes can have a significant impact on debtors' balance sheets or the profitability of banks (Amato and Gerlach 2002). Consequently, the stable exchange rates are one of the major factors to prevent banking crises. Thirdly, it is associated with joining the European Monetary Union (EMU) for these new member countries. Joining the euro was conditioned to participate in the ERM II, and the stability of foreign exchange market is deemed to be a necessarily condition. Slovenia joined the ERM II in 2004, and adopted the euro in 2007. The inclusion of Slovenia would provide a useful insight into joining the single currency for the non-euro new EU countries. In this respect, our study may be contributory to policy makers by delivering policy options concerning the course of actions to stabilise their foreign exchange markets and safeguard the value of currency.

It is found that the empirical results do not seem to provide a consistent, robust support for the fundamentals as the determinants of the persistence of crisis. Whilst macroeconomic and financial fundamentals may be useful indicators of the triggering of the currency crisis, some of them may no longer be robust sources during the crises period. Also, a finding of the varying effect of fundamentals across countries seems to reflect a heterogeneous process in their economic and financial development in these transition economies. The evidence highlights the lagged probability of a high volatility regime as the major cause of persistence in currency crisis in all cases. This appears to support the self-fulfilling nature of speculative attacks put forward by Obstfeld (1986 and 1996).

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 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:

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

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. D denotes the first-difference operator. The weights *a, b* and *g* 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 the exchange rate, a sharp increase in the interest rate, and decline in reserves raise the index of exchange market pressure. 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 assume that *empi* 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 volatility, and $S_t = 1$ denotes a period of high volatility. *empi*, which is conditional on the value of S_t is given by

$$empi_t = \alpha_0(1 - S_t) + \alpha_1 S_t + \sigma(S_t)\varepsilon_t \tag{2}$$

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),

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

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

$$0 < p_0 < 1, 0 < p_1 < 1$$

where p_0 and p_1 are fixed transition probabilities of being in tranquil and high volatility 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*,

$$\Pr_t = \Pr(S_t = S \mid empi_t, \ldots, empi_1) \tag{3}$$

These provide information about the state, in which $empi_t$ is most likely to be at every point of observations in the sample. It is assumed that when *empi* is in a high volatility regime, there is an intense increase in speculative pressure on a currency, which is indicative of a crisis. The filtered probability, which indicates the probability of staying in a high volatility regime, can be interpreted as the persistence in currency crisis in this paper. This enables us to explore the driving forces of the persistence.

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 its behaviour during non-crisis periods. We take such indicator variables as the driving force to a high volatility regime in *empi* in this paper.

It is argued that crises were associated with expansionary monetary and fiscal policies and also excessive domestic credit, leading to a substantial loss of foreign reserves under a fixed exchange rate regime (Krugman 1979). With the loss of reserves, yet under the circumstances in which the authorities adhere to parity, domestic interest rates have to increase and stay at a high level. The adverse consequences are a fall in the level of output and employment due to a higher level of borrowing costs. The detrimental effects of an expansionary policy may also be translated to 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. Also, under a 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. However, domestic interest rates need to be raised more than an increase in foreign interest rates due to the depletion of foreign reserves. On the other hand, if foreign interest rates exceed a tolerable level, the cost of maintaining the exchange rate may outweigh the benefits, since high domestic interest rates dampen both investment and output. Moreover, banking crises can be reflected in the adverse movement of deposit rates together with a decline in deposits and the spread between lending and deposit rates. In any of these circumstances, which engulf a vulnerable currency, the likelihood of a highly volatile *empi* is inevitable.

With the above theoretical aspects of a crisis, and also with the data availability on a monthly basis, we can classify the variables into five groups of current account indictors, capital account indicators, real sector indicators, financial indicators and also external indicators[8]. We explore a broad range of 17 dependent variables as the

Table 1a
Indicators of Fundamentals

Indicators	*Notations (expected sign)*	*Potential impact based on literature*
Current account indicators		
Deviations of the real exchange rate from the trend[2]	*reex_w* (-) or (+)	A large misalignments of the real exchange rate is linked to instability.
Trade balance: Imports and exports:	*im-ex* (+)	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[3]	*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[4]	*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, and all variables satisfy the stationarity.
[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]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.
[4]The foreign interest rate is a weighted average of US (35%) and Germany (65%).

Table 1b
Correlation of the Indicators

	reex_w	*im-ex*	*fr*	*m2/fr*	*rid_w*	*fl/fr*	*ip*	*stock*	*m2/bm*	*dc*	*rdr*	*lr/dr*	*exm1*	*dep*	*ip_us*	*ip_gm*	*oil*
reex_w	1.00																
im-ex	0.03	1.00															
fr	-0.06	-0.03	1.00														
m2/fr	0.16	0.11	-0.88	1.00													
rid_w	-0.04	0.04	0.14	-0.03	1.00												
fl/fr	0.05	0.07	-0.14	0.16	0.01	1.00											
ip	0.06	-0.08	0.00	0.00	0.02	-0.07	1.00										
stock	-0.03	0.03	0.01	-0.01	-0.05	0.02	-0.05	1.00									
m2/bm	-0.02	-0.03	-0.06	0.10	0.01	0.09	0.00	0.00	1.00								
dc	-0.02	0.01	-0.27	0.28	0.03	0.02	0.01	-0.08	0.02	1.00							
rdr	0.09	0.17	-0.07	0.09	0.12	0.07	0.08	0.05	-0.03	0.07	1.00						
lr/dr	-0.04	0.04	0.05	-0.03	-0.05	0.00	-0.07	-0.04	-0.11	-0.03	-0.23	1.00					
exm1	-0.03	0.19	0.04	0.02	0.02	0.01	-0.78	0.03	-0.09	0.14	0.20	0.02	1.00				
dep	0.04	0.28	0.04	0.18	0.05	-0.01	-0.07	-0.05	0.11	0.22	0.19	0.06	0.29	1.00			
ip_us	0.01	-0.15	0.04	-0.01	0.06	-0.05	0.26	-0.01	-0.10	0.04	0.05	-0.03	-0.20	-0.01	1.00		
ip_gm	0.03	-0.20	-0.05	0.01	0.02	0.01	0.50	-0.07	-0.03	-0.04	0.00	-0.06	-0.47	-0.22	0.06	1.00	
oil	-0.06	-0.08	0.00	-0.05	-0.06	-0.05	-0.01	-0.05	0.06	-0.09	-0.06	-0.03	-0.02	-0.11	0.05	0.02	1.00

Mean of the correlation across countries is calculated. Correlation for individual countries is more or less at a similar level.

determinants of high volatility in *empi* in the Czech Republic, Hungary, Poland, Slovakia and Slovenia over the sample period 1994:01 to 2006:12.

Data are listed in Table 1a with the abbreviation of each variable and the predicted sign based on theoretical and empirical literature on currency crises. The (+) implies that an increase in variables is associated with a high volatility, whilst the (-) indicates that the decrease in variables is with the high volatility period. Data are all collected from International Financial Statistics, except for base money and oil price, which are retrieved from Datastream. The benefit of a relatively large number of explanatory variables is to widen the scope of the determinants, but the cost may arise as a potential multicollinearity problem. However, the inspection of correlation shown in Table1b hardly presents such a concern, since except for a few cases, correlation falls to less than 0.3.

4. EMPIRICAL RESULTS

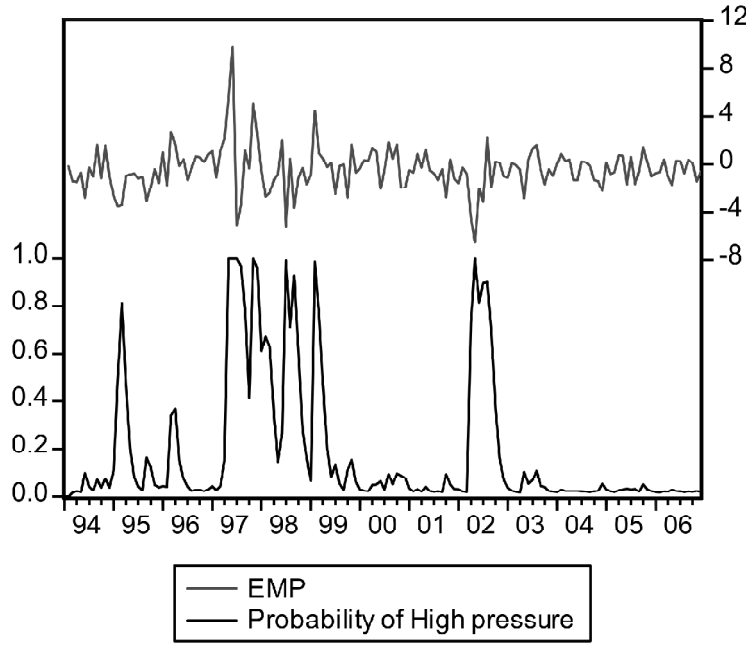
4.1. Markov Switching Model

Table 2
Estimates from the Two-state Markov Switching Model with the Fixed Transition Probabilities

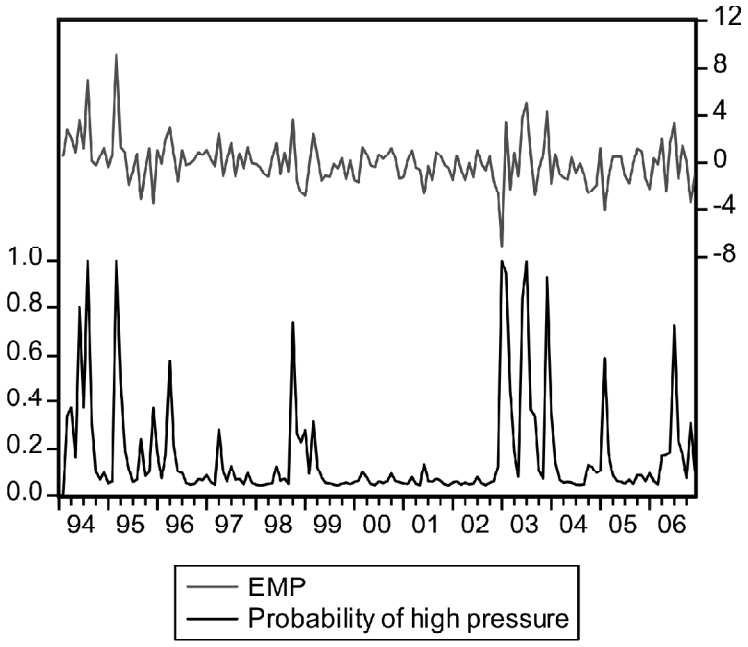
	Czech	*Hungary*	*Poland*	*Slovakia*	*Slovenia*
$\alpha 1$	-0.411	1.180	-0.1001	0.603	-0.668
	(-0.580)	(1.424)	(-0.331)	(0.557)	(-1.064)
$\alpha 0$	-0.431	-0.184	-0.698	-0.350	0.057
	(-3.825)	(-1.276)	(-4.444)	(-3.022)	(0.453)
$\sigma 1$	12.430	11.417	4.6279	20.373	10.555
	(3.533)	(2.613)	(4.468)	(2.066)	(3.719)
$\sigma 0$	1.433	1.712	2.257	1.548	1.759
	(6.501)	(4.675)	(6.066)	(6.513)	(6.210)
p1	0.854	0.542	0.967	0.658	0.946
	(2.537)	(0.164)	(3.318)	(1.046)	(2.738)
p0	0.964	0.906	0.984	0.952	0.985
	(4.211)	(2.615)	(4.290)	(6.293)	(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	34.22	10.32	63.62	42.06
	[0.000]	[0.000]	[0.065]	[0.000]	[0.000]
Further testing of the hypothesis:					
$\alpha 1 = \alpha 0$	0.001	1.876	1.133	0.760	1.377
$\sigma 1 = \sigma 0$	7.123	3.906	4.015	5.615	9.872
$p1 = p0$	3.427	2.425	0.314	10.393	1.540

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. The numbers in the equality tests are chi-square, with critical value being 3.84 at the 5 per cent significant level.

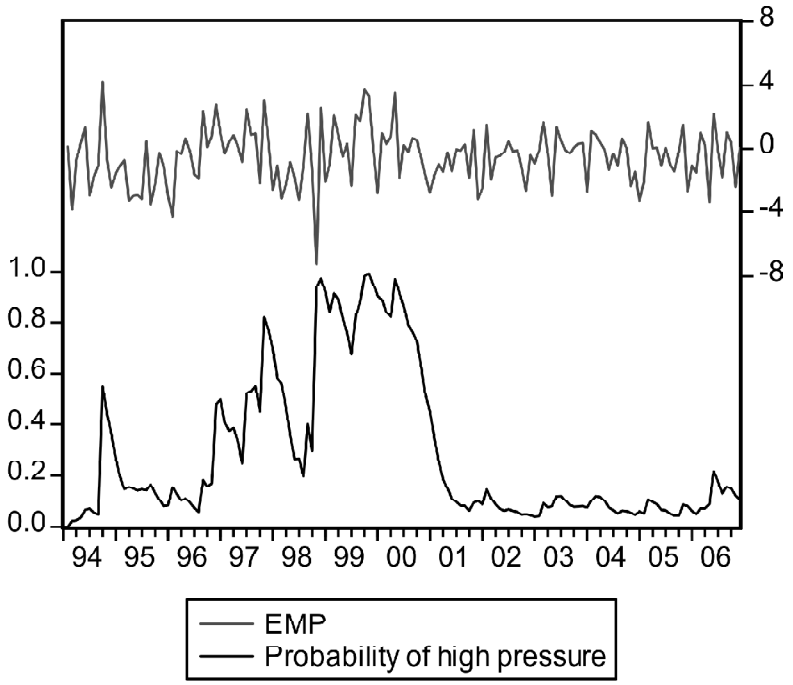
Figure 1: *empi* (top plot) and Probability of High Volatility Period based on MSM (Bottom Plot)



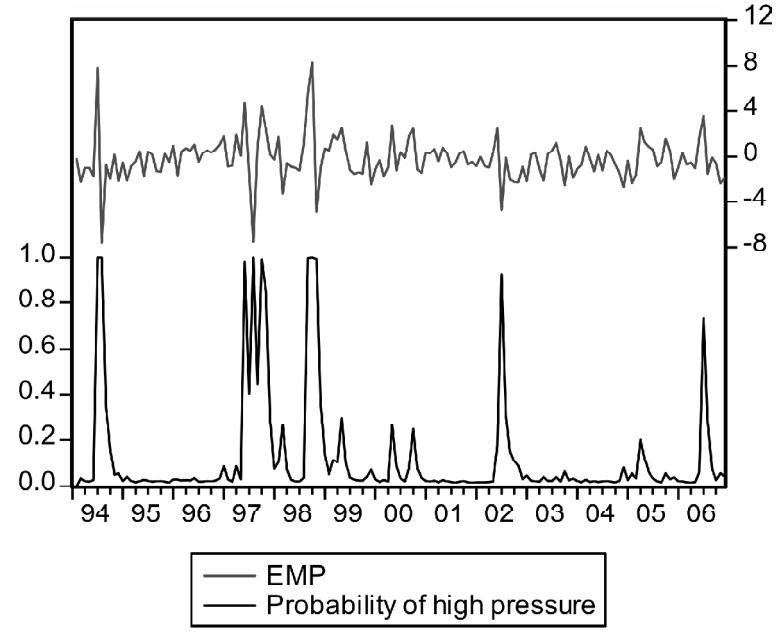
(a) Czech Republic



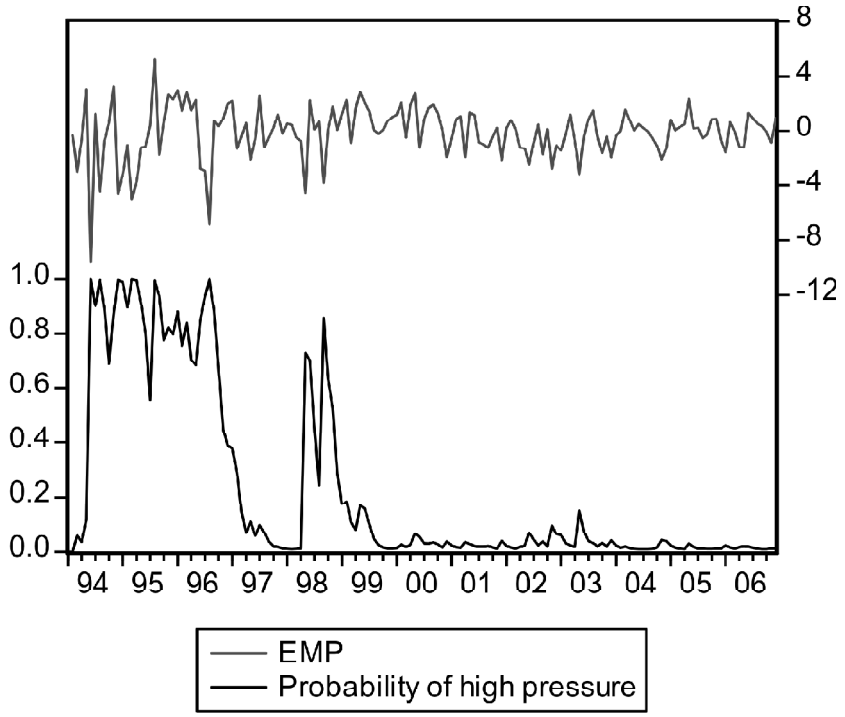
(b) Hungary



(c) Poland



(d) Slovakia



(e) Slovenia

Note: The exchange rate systems of the five new EU countries

Czech Rep.	1995	Bands widened from ±0.5% to ±7.5%
	1997 May	Currency crisis. 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.	Currency crisis. Managed floating
Slovenia	1993 to 2004	Managed floating
	2004 June	Joined the ERM II from managed floating
	2007 Jan	Joined the euro

Table 2 shows the estimates from MSM for the five countries. The Davies's (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 of the cases, confirming the nonlinearity. It appears that regime switching in the mean is not significant, since the null hypothesis of $\alpha 1 = \alpha 0$ is not rejected in all of five cases. However, the volatility, indicated by the estimates of σ in both states is statistically highly significant at above 1 per cent level, and the null hypothesis of $\sigma 1 = \sigma 0$ is rejected in every cases. Further, there is a large difference in the magnitude of the coefficient between regime 1 ($\sigma 1$) and regime 0 ($\sigma 0$). These results provide the crucial statistical evidence that there exists two volatility regimes of tranquil and crisis periods in the series of *empi*. State 0 can be identified as a low-volatility regime, whereas state 1 is a high-volatility regime. The hypothesis test of two regime probabilities in the last row in Table 2 shows that, apart from Slovakia, there is no statistical significance between *p1* and *p0*, suggesting that the duration in one regime is somewhat equal to that in the other regime over the sample period.

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 filtered probability of likely high volatility regime of *empi* derived from MSM at the bottom with the scale on the left hand for comparison. The charts show that large fluctuations in the level of *empi* appear to correspond well with the probability of high volatility, where we tend to find major events or policy changes leading to speculative pressure on the currency.

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, these countries tended to experience high volatility in *empi,* 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 market. Over the Asian and Russian crises period in 1997-98, the volatile market is also evident, yet it is not certain whether this is solely due to the contingent effect, since at the same time these countries had their own currency crisis and/or the changes in the exchange rate systems.

The introduction of the 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 in 1997 and 1998 respectively[10]. At the time of currency crisis, the *empi* peaked with almost 100% probability of staying in high volatility regime. The only exception is for Hungary, where it had a low volatility when a floating system was adopted in 2001, yet the effect may be felt afterwards as it exhibits a high volatility in 2002-2003, and this might have coincided with a concern in joining the EU. When Hungary and Poland widened the band as large as around 15% in 1998, the high volatility is evident. The Maastricht exchange rate criteria imply a participation in the ERM II mechanism for new EU countries as a prerequisite for joining the single currency. Slovenia opted for the ERM II in 2004 from the managed floating system, and joined the euro in January 2007. The low probability of high volatility is sustained for Slovenia since around 1999 onward leading to joining the monetary union in 2004.

4.2. Linear Regression Models

Table 3
Linear Analysis with the Dependent Variable of the Filtered Probability (Pr) with a High Volatility Regime

	Czech		*Hungary*		*Polan*		*Slovakia*		*Slovenia*	
	Coef.	*(t-Stat)*	*Coef.*	*(t-Stat)*	*Coef.*	*(t-Stat)*	*Coef.*	*(t-Stat)*	*Coef.*	*(t-Stat)*
C	0.019	(1.082)	0.033	(1.329)	0.007	(0.507)	0.050	(2.682)	-0.039	(-2.858)
Pr_{t-1}	0.814	(17.648)	0.426	(6.073)	0.945	(32.729)	0.546	(8.130)	0.967	(35.198)
$reex\_w_{t-3}$					-0.288	(-1.370)	0.741	(1.737)	0.537	(2.309)
$im\text{-}ex_{t-1}$					0.329	(2.020)	-0.235	(-1.329)	0.169	(1.469)
$_{t-2}$					0.251	(1.562)			0.216	(1.760)
$_{t-3}$					0.236	(1.555)				
fr_{t-2}				-0.774	(-2.084)					
$m2/fr_{t-1}$	0.294	(1.241)	1.132	(2.362)	-0.200	(-1.187)	-0.219	(-1.762)		
$_{t-2}$					-0.646	(-2.115)				
ip_{t-1}	1.612	(4.152)			-0.373	(-1.754)			0.869	(1.805)
$_{t-2}$	0.741	(2.109)							1.089	(2.308)
$stock_{t-1}$	-0.254	(-1.301)	-0.460	(-2.753)	-0.159	(-1.467)	-0.307	(-1.459)		
$_{t-3}$					-0.168	(-1.760)	-0.344	(-1.598)		
$m2/bm_{t-1}$			0.651	(1.500)						
$_{t-2}$			1.078	(2.611)						
$_{t-3}$			1.768	(4.445)						
$_{t-4}$			0.823	(1.933)						
dc_{t-1}			2.864	(2.803)	0.821	(1.657)	0.757	(1.658)		
$_{t-3}$		2.340	(2.302)					2.043	(4.363)	
$exm1_{t-1}$	1.300	(4.470)	0.304	(1.587)	-0.357	(-1.655)			0.224	(1.667)
$_{t-2}$	0.658	(2.309)	0.366	(1.855)					0.381	(2.971)
dep_{t-2}					0.933	(1.797)			1.323	(1.985)
lr/dr_{t-1}	0.153	(1.056)	0.534	(1.543)					0.253	(2.333)
rdr_{t-1}			0.018	(1.159)			0.037	(2.976)	0.025	(5.778)
$_{t-3}$							0.018	(1.412)		
ip_us_{t-1}	2.837	(3.097)			2.158	(3.877)				
$_{t-2}$	2.303	(2.363)			1.191	(1.762)				
ip_gm_{t-1}					0.310	(1.866)	-0.413	(-1.754)	0.253	(1.866)
oil_{t-1}	-0.372	(-2.075)	0.353	(1.820)			0.306	(1.468)		
R^2	0.72		0.46		0.92		0.44		0.91	
	Chi sq.	prob.	Chi sq.	prob.	Chi sq.	prob.	Chi sq.	prob.	Chi sq.	prob.
LM serial 1	1.973	[0.160]	0.698	[0.404]	1.636	[0.201]	0.907	[0.341]	0.018	[0.894]
LM serial 2	2.151	[0.341]	2.951	[0.229]	1.676	[0.433]	1.779	[0.411]	5.147	[0.076]
Hetero	10.949	[0.448]	30.773	[0.009]	40.066	[0.003]	21.556	[0.028]	24.541	[0.027]
Predictability:										
RMSE	0.259		0.165		0.197		0.216		0.270	
MAE	0.193		0.117		0.150		0.144		0.225	

Breusch-Godfrey Serial Correlation LM Test.
Heteroskedasticity Test: Breusch-Pagan-Godfrey. t-ratios are adjusted by the white hetero skedasticity adjusted standard error.
EMSE: Root Mean Square Error; MAE: Mean Absolute Error.

A regression analysis is conducted with the filtered probability of the high volatility regime in Figure 1 as the dependent variable and with the indicators listed in Table 1 as the explanatory variables. We specify lagged regressors up to 4 lags in order to capture developments in the economy and to derive true 'driving forces' prior to the crisis. This is also to avoid the endogenous effects of crises on the explanatory variables. Given a relatively large number of variables, the linear model is conducted from general to specific method by removing variables which have a very low significance level[11].

See Table 3. It is evident that the performance of each indicator widely varies across countries, and some of the predicted sign on the indicators is violated in some countries. The results bear a number of country-specific determinants, which should merit more scrutiny for individual countries judged by the standard significance level of 5%.

Expansionary monetary policy (*exm1*) is likely to be the cause of the high volatility regime for the Czech Republic. As opposed to the predicted sign, the expansion of domestic real sector *(ip*) and US growth (*ip_us*) is also responsible for the instability. In Hungary, monetary and credit expansion (given a positive sign on *m2/fr*, *m2/bm* and *dc*) may destabilise *empi* induced by speculative pressure. A fall in the stock market (*stock*) seems to be contributory, as well. In Poland, a worsening trade balance (*im-ex*) and a decline in the foreign exchange reserves (*fr*) may be critical indicators of the persistence in the volatile foreign exchange market. Also, conflicting with the existing literature, the contraction of money supply (*m2/fr*) seems to be a concern in Poland, as it appears to be leading to a fall in growth *(ip)*. The deviation of the real exchange rate from the trend (*reex_w*) should be monitored in Slovenia, since a large misalignment is likely to lead to a high volatility. Speculative pressure may be driven by the potential conditions for banking crises in Slovakia and Slovenia: A high ratio of lending to deposit rates *(lr/dr)* reflects a decline in the quality of loans, leading to an increase in non-performing assets and default rates, also a high real deposit rate (*rdr*) may indicate a liquidity problem in the banking sector.

By cross-examining the empirical results, the effect of indicators is not consistent across countries. The current account balance did not receive much support as a useful indicator of crises other than for Poland and Slovenia. The variables associated with the capital account did not fare well either in some of these countries, despite the fact that the decline in foreign reserves is traditionally supported as the cause of a currency crisis; the real sector and external indicators have little predictive power in Hungary and Slovakia. The expansion of money and credit exerts a weak effect in Slovakia, given only a 10% significance level on the coefficients of *m2/fr* and *dc*. The adverse movement of interest rates seems to matter only in Slovakia and Slovenia. The different results across countries appear to reflect a heterogeneous process in their economic and financial developments. It alerts us to the fact that the assumption of parameter equality across countries, based on a panel of countries in the currency crisis literature (for example, Martinez-Peria 2002 and Fiess and Shanker 2009), may result in poor predictive performance.

These results can be compared with the study of the 'warning system', where a broad variety of indicators are found, and currency crises seem to be preceded by multiple economic variables[12]. In this respect, macroeconomic and financial fundamentals may indeed be useful indicators for triggering the currency crisis, yet some of them may no longer be robust sources during the crisis periods.

The crucial finding, among others in Table 3, is that in all cases the lagged dependent variable (pr_{t-1}) has shown itself to be highly significant, playing a dominant role in the high volatility regime. This seems to support the self-fulfilling nature of speculative attacks (Obstfeld 1996). Obstfeld (1986) emphasizes the endogenous economic policies and agents' expectations: Policymakers respond to changes in the economy, and agents' expectations are formed based on such 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 economy move from one equilibrium to another without a significant change in the fundaments, but with changes in agents' expectations (Kaminsky *et al.* 1998). An implication of self-fulfilling crises is that it may be very difficult to find a defined relationship between fundamentals and crises, since crisis may be persistent without a previous significant change in fundamentals.

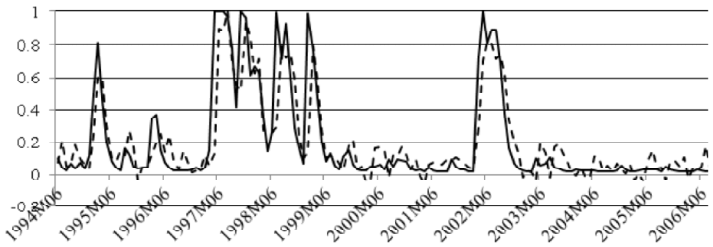
As a robustness test, we conducted the predictability and forecast tests on the fitted values derived from the linear model. The predictive validity of the model is evaluated by the Root Mean Square Errors (RMSE) and Mean Absolute Error (MAE)[13], where large values indicate that the model performs poorly in terms of an ability to track the actual value of the dependent variable, i.e. the filtered probability. (See the last two rows in Table 3). It seems that the size of the errors between fitted and actual values is within a plausible range, given the maximum value of 1 (100%). For the forecast validity, we plot the fitted probability values against the actual probability values in Figure 2, which shows the time path of tracking performance. When the high volatility regime has a low probability of less than around 20%, the power of forecast seems to be weak as there is some deviation between fitted and actual values. However, when the probability is high, the fitted value performs remarkably well by correctly tracking the turning points and fluctuations. Given that the most interest lies in the high volatile probability, rather than the low volatile probability, the level of forecast performance serves to provide credibility for the estimated model.

5. CONCLUDING REMARKS

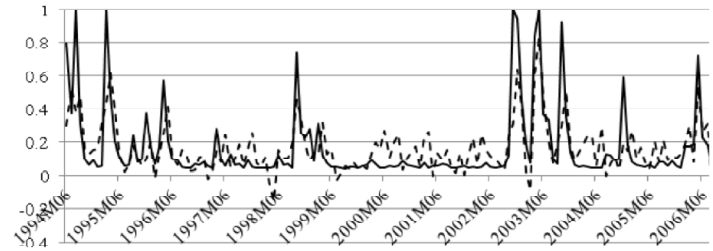
The main objective of this paper is to investigate the determinants of the high volatility regime in exchange market pressure which is associated with the persistence of currency crises in some new EU member states. The model developed in this paper allows that the probability of being in a high volatility regime is a function of various determinants. Following the 'early warning' literature, we assumed that the detrimental movements of macroeconomic and financial variables would sustain the crisis. Yet, our results supported less the fundamentals as the

Figures 2: Fitted (Dotted Line) and Actual (Solid Line) Probability Values of High Volatility Regime

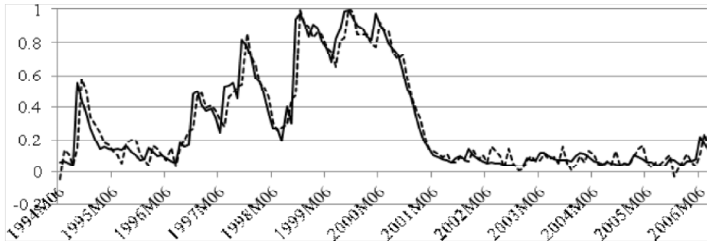
Czech Rep.



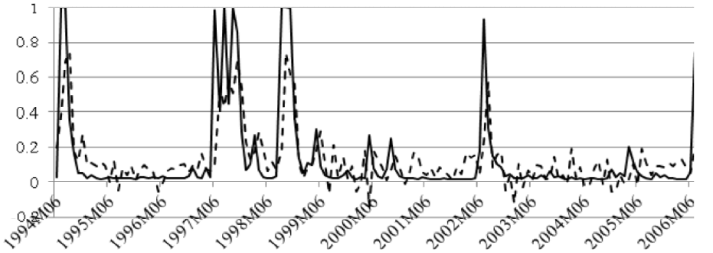
Hungary



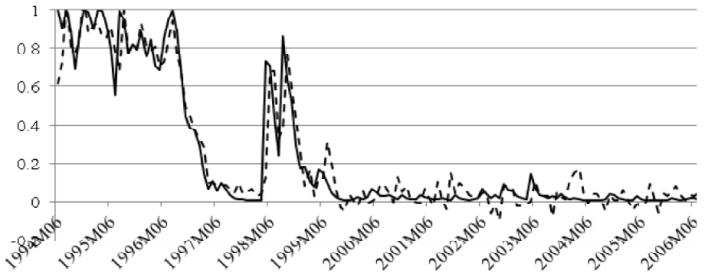
Poland



Slovakia



Slovenia



determinants of the currency in crisis, but more the self-fulfilling nature of a currency crisis.

Notes

1. This is a revised version of the paper presented at the 9th Annual Conference of the European Economics and Finance Society (EEFS), held at Athens, Greece in June, 2010. The authors are grateful to the participants of this conference for their helpful comments and suggestions.
2. Most of the previous studies exclusively focused on devaluation episodes. Exchange rate market pressure is a broader definition of crises, which include not only devaluations, but also episodes of unsuccessful speculative attacks, hence it provides much greater insight into the currency-crisis literature.
3. We concentrate on the five large 'first' waves of new EU member states in the Central Eastern Europe region due to data availability.
4. In recent years, it has also been applied to the currency crisis analysis. See, e.g. Jeanne and Masson (2000), Cerra and Saxena (2002), Fratzscher (2003) and Abiad (2003).
5. The value of a threshold is determined, and any value of the index that exceeds the threshold value is classified as a high pressure. This is referred to as the dating procedure.
6. 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 no loss of information. However, such a model strategy may be impractical in the current study. With a large set of indicator variables specified, in preliminary estimation the major limitation was the difficulty in detecting significant coefficients and also in obtaining convergence. Several empirical attempts by applying TVTP were also not successful. See, e.g., Cerra and Saxena (2002) who analysed Indonesia's currency crisis, and Abiad (2003) who studied the Asian crisis episode during the period 1972-1999. See also Martinez-Peria (2002) who investigated the speculative attacks on the European Monetary System. In many cases, they failed to find statistically significant coefficients by the TVTP. Hence, we do not pursue this strand.
7. For example, the available data show that a high proportion of NPL at the 29.3% of GDP is recorded for the Czech Republic in 2000 and 18.6% for Poland in 2001 (World Development Indicator).
8. Contagion effects are commonly found in currency crisis (e.g. Gerlach and Smets 1994, Cerra and Sacena 2002). For example, the devaluation in one country may trigger devaluation in neighbouring countries in order to maintain price competitiveness, or contagion effect also may arise due to investors' herding behaviour, paying little heed to countries' economic fundamentals (Eichengreen et al. 1995 and Calvo and Reinhard, 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 the neighbouring countries is found to be insignificant in all cases, and also there is an inadequate data availability of political variables on a monthly basis. We do not pursue these strands.
9. The Davies's (1987) test that is based on an adjustment to the Likelihood Ratio test statistic provides an upper bound for the correct probability value.

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. In this respect, *fl/fr* and *rid_w* are removed.
12. 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 high ratio of broad money to international reserves for twenty developed and emerging economies using monthly data from 1970 to 1997.
13. Root Mean Square Error = $\sqrt{\frac{1}{T}\sum_{t=1}^{T}(F_t - A_t)^2}$ and Mean Absolute Error = $\frac{1}{T}\sum_{t}|F_t - A_t|$ where F_t = fitted series, A_t = actual series, and T = number of periods.

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