The Financial Crisis in Central and Eastern Europe: the Measures and Determinants of the Exchange Market Pressure Index and the Money Market Pressure Index

Fabio Filipozzi
Bank of Estonia and Tallinn University of Technology
Estonia pst 13, 15095 Tallinn, Estonia
Phone: +372 6680964, e-mail: fabio.filipozzi@eestipank.ee

Kersti Harkmann
Bank of Estonia and Tallinn University of Technology
Estonia pst 13, 15095 Tallinn, Estonia
Phone: +372 6680924, e-mail: kersti.harkmann@eestipank.ee

Abstract

This paper discusses how the global financial crisis has affected the formation of exchange rates and interest rates in three major Central and Eastern European countries: Poland, the Czech Republic and Hungary. Two main channels of the transmission of the crisis are considered: the exchange rate channel, measured by the exchange market pressure index (EMP), and the interest rate channel, measured by the money market pressure index (IMP). Two key results are achieved by using panel regressions. First, during the recent crisis the interest rate channel was controlled by authorities, who left the exchange rate to be the absorber of the imbalances created before the crisis. Second, even though the crisis transmitted through to the banking sector, monetary and external imbalances contributed to the vulnerability of the countries analysed here. The government sector seems to have had a minor role in creating the conditions for the crisis, while it played a central role in taming the effects of the crisis.

JEL classification codes: F30, G01, E44
Keywords: currency crisis, exchange rates, exchange market pressure index, money market pressure index, financial crisis, CEE

1. Introduction

After a period of strong expansion of economies across the world, in 2007 a crisis burst out in the real estate sector of the United States. With the collapse of Lehman Brothers in 2008 the crisis soon became global. Initially, it primarily affected the advanced economies of the United States and Western Europe, but the spillover of the crisis was unexpectedly powerful and, among others, also affected Poland, the Czech Republic and Hungary – members of the European Union waiting for accession to the euro-zone. The financial crisis has been equally exciting as it has been complicated, the relationships between money and exchange markets and the crisis are relevant for research.

The objective of this paper is to discuss how the global financial crisis has affected the exchange and money markets in three major Central and Eastern European countries: Poland, the Czech Republic and Hungary. More specifically, the paper addresses four questions:

- Did the crisis hit the three major CEE countries in the same way?
- Which roles have the exchange rate and interest channels played in the transmission of the financial crisis to Poland, the Czech Republic and Hungary?
- Which factors have created the preconditions for the crisis and which ones have evolved simultaneously with the crisis?
- Which role has the authorities taken?

The paper examines two main channels of transmission of the financial crisis to Central and Eastern Europe. The first one is the exchange rate channel. The approach for measurement is the exchange market pressure index (EMP), developed by Girton and Roper (1977) initially and later by Eichengreen et al. (1996), which consists of changes in exchange rates, changes in interest rates and changes in international reserves.

The second one is the interest rate channel of money markets. Central banks reacted to the crisis with active monetary policy measures, which resulted in several interest rate cuts to historically low levels. However, interbank interest rates seemed to skyrocket, possibly "neutralising" central banks' efforts to combat the crisis. In order to consider the effect of interest rates changes on the three countries in question, the analysis of the money market pressure index (IMP), developed by Hagen and Ho (2007), is conducted in parallel with the EMP analysis.

Given that the crisis is characterised by illiquidity, it is assumed that central banks intervened mostly in money markets and the banking sector while leaving the exchange market aside. Thus, we expect the EMP to show a more distinct behavior, as the IMP is strongly controlled by central banks.

Monthly data for Poland, the Czech Republic and Hungary are used to study the dynamics of exchange and money market pressure indices in these countries. Later, the EMP and IMP indices are subsequently regressed on several different explanatory variables to understand the impact that both external and internal factors had on the indices, and accordingly their role in the effects and development of the crisis.

By using the EMP and IMP indices, it is possible to define a binary dependent variable, showing the real moments of the crisis. We use this approach for logit analysis. The main novelty of the current research stands in the contemporaneous consideration of the EMP and IMP, and in the focus on Eastern European countries. To the authors' knowledge, this is also the first attempt to study the influence of the recent crisis on the exchange and money

markets in the CEE during 2001–2009. Furthermore, we try to distinguish between the different variables and to group them into those causing vulnerability and those reacting to the crisis.

The rest of the article is structured as follows. Section 2 gives an overview about the theoretical literature on which the empirical analysis is built. Section 3 covers the problems related to the construction of the Exchange Market and money market pressure indices. In Section 4, the data and approach for the calculation of indices are described. Section 5 is dedicated to the empirical analysis of the constructed indices. Section 6 concludes.

2. Review of Theoretical Literature

Part of the theory of crises in the financial world looks at whether crises are exceptional events or not, while trying to identify why they happen. In general, there are two opposing views about the occurrence of crises. One states that crises in general are very random events that happen independently of any real changes in the economy, so that the occurrence of a crisis can not be influenced or caused by anything specific and crises exist of themselves. The other view is that financial crises are a natural part of the business cycle and are caused by changes in the real economy (Gorton, 1988; Allen and Gale, 1998).

This divergence of views also applies to the financial and foreign exchange markets during periods of distress. Currency crises in general can be defined as a rapid and extreme change in the exchange rate, which may happen because of a speculative attack on a country's currency that could result in devaluation. Several different approaches, often referred to as generations of models, have tried to explain why the crises occur, and these will be discussed in the next sections.

The recent turmoil in financial markets has once again made the crises the object of several studies. The theories explaining the currency crises, broadened also for the financial crises, can be divided into three groups or three generations of models.

According to the first-generation models, originally developed by Krugman (1979) and Flood and Garber (1984), a financial crisis can be foreseen as it is only a result of bad policy combinations that lead to a deterioration of fundamentals. Though the first-generation models mainly dealt with crises that originated in the currency markets, they could also be applied to financial markets. The models explain crises as a consequence of the inability of governments to run a strict fiscal policy as excessive money creation to finance a deficit creates excessive devaluation pressure on the currency.

As a result, money growth is not compatible with a currency peg as market participants realise that there is a contradiction in the fundamentals, and they try to convert the currency to a foreign one, thus creating more downward pressure as the supply of domestic currency increases. In order to support the peg, the central bank is forced to buy domestic currency and use up its foreign reserves or to increase its interest rates. The real actual crisis itself occurs when mass selling of the domestic currency starts.

Overall, according to the first-generation models, crises are connected with weak fundamentals; such as budget deficits, current and trade account deficits, a fall in international reserves and an excessive real money supply (Belke and Setzer, 2004; Vaugirard, 2007).

The second-generation models explain crises as a consequence of the expectations of investors and a change in market sentiment in the presence of multiple equilibria. The

models also consider the possible trade-offs between different policy decisions. These models, originally credited to Obstfeld (1994; 1996), suggest that expectations are self-fulfilling, meaning that if investors believe that there will be a crisis then there will indeed be a crisis. This will happen mainly because investors change their behaviour according to their beliefs. Therefore, according to the second-generation models crises are possible even with strong fundamentals (Belke and Setzer, 2004; Vaugirard, 2007; Flood and Marion, 1998).

Second-generation models also help to explain the reasons why crises tend to spread across borders. If there is a crisis in one country, it increases the likelihood of a crisis in another country. In general, the crises could occur contemporaneously because of a common shock that influences, for example, a particular region. The crisis could spread across the borders between close trade partners. This may happen because the problems in one country may affect the other through a fall in exports and prices. The spillover may be also caused by changes in beliefs and sentiment and thus caused by self-fulfilling expectations (Eichengreen et al., 1996).

The third-generation models emphasise the importance of financial institutions and the banking sector in creating crises alongside structural flaws and policy inconsistencies, and also stress the importance of macroeconomic fundamentals and expectations. Krugman (1998) was one of the first to discuss the role played by moral hazard and bubbles in the financial world in creating crises, following the Asian crisis of 1997. However, the third-generation models differ between authors and there is no clear consensus about the issue among authors.

One approach explains crises as a consequence of the moral hazard that accompanies over-borrowing by banks in an environment of financial liberalisation without prudential supervision. A crisis occurs when the imbalances in the financial sector trigger capital flight or liquidity problems in the markets (Krugman, 1998; Corsetti et al., 1998; Poeck at al., 2007).

In addition, banks that have currency mismatch in their balance sheet are exposed to credit and liquidity risks. Banks could face moral hazard as they lend money out at higher rates than those they paid to raise it. Risky investments are financed by the higher rates, and ultimately this causes asset price bubbles, lifting the prices of risky assets and making the banks seem sounder than they actually are. It is believed that a crisis occurs when the bubble bursts and then the processes go into reverse. The prices of risky assets fall and therefore the banks become insolvent. The fall in asset prices causes capital flight, which can become a mass flight that results in more pressure on the currency than can be defended against by the central bank. Moral hazard is an important feature of these models, as foreign investors are unable to identify the true risks faced by the banks. In general, banking sector weakness, foreign capital exposure and the level of domestic credit growth are believed to be the crisis indicators, or even triggers (Kaminsky and Reinhart, 1998, 1999; Burnside et al., 1999, 2001, 2007; Sarno and Taylor, 2002; McKinnon and Pill, 1996).

Third-generation models have sometimes also covered the contagion of financial crises, looking at crises that spread across borders excessively without any fundamental reason. The spread of a crisis due to herd-like behaviour and excess panic is like an avalanche that cannot be stopped.

These models also discuss the importance of interest rates in the economy. According to first generation models, increasing the interest rates should help to protect the peg by increasing the demand for the domestic currency. The third-generation models argue that increasing the interest rates results in a lack of funding alternatives for the private sector and

thus pushes down investments and output. It has now been seen that it is not only the central bank interest rate that influences a crisis, but also the interbank rates.

Even though the early works on crises dealt mainly with currency crises, different types of crisis have occurred during the past. It is clear today that these types of crisis are not independent of one another. One type could easily transform into another and thus create more distress. It could be argued that the recent crisis combines different types of crises. In addition, the models were originally meant to explain the theory behind the fixed exchange rate, but they could apply equally to floating exchange rate arrangements. Overall, it can be said that the main factors connected with crises are banking sector fragilities, extensive and uncontrolled credit growth, and poor macroeconomic conditions.

It is clear why it is so difficult to define a crisis in a way that makes it possible to measure it. The following section gives an overview of one method that should help to define, characterise, analyse, and measure crises in both foreign exchange and money markets.

3. Financial Crises Indices

3.1. Construction of the Exchange Market Pressure Index

In order to analyse the severity of a crisis and the influence that various factors have on it, a definition of crisis is needed that could be used in empirical analysis. To identify periods of crisis, an index could be built that reflects the changes.

The exchange market pressure index was first developed by Girton and Roper (1977) as they studied the changes in the exchange rate for Canada. Their index helps to identify currency crises as moments when an exchange rate is under pressure or even under speculative attack.

The Girton-Roper model includes movements in the exchange rate and international reserves in their work. Weymark (1995, 1998) also offered an approach for small open economies starting from the same point. They suggest that money market disequilibrium is caused by excess demand for foreign currency and the need for rebalancing by depreciation of the exchange rate or by changes in international reserves.

The basic exchange market pressure index can be extracted (Bird and Mandilaras, 2006):

$$EMP_t = \alpha \Delta e_t - \beta \Delta r_t + \gamma \Delta i_t \ , \qquad (1)$$

where; e_t is the exchange rate at time t; i_t is the short-term interest rate at time t; and r_t is the level of reserve assets at time t.

There is no consensus on the weights α, β, γ of each component. In several studies it has been suggested that the variables should be equally weighted so that the sum of weights equals zero. In other studies, it has been suggested that the components should be corrected for volatility.

To study contagion in the exchange market, Eichengreen et al. (1996) use a differently constructed composite index. The index is calculated by changes in exchange rates, interest rate differentials and changes in the reserve assets in country i at time t. In their study, all the data has been measured against German data, but the anchor country could also be other than Germany. In addition, the authors suggest adjusting the index variables for volatility.

This can be expressed as (Dungey et al., 2004; Haile and Pozo, 2008):

$$EMP_{i,t} = \alpha\Delta e_{i,t} + \beta\left(i_{i,t} - i_{0,t}\right) + \gamma\left(\Delta r_{i,t} - \Delta r_{0,t}\right), \quad (2)$$

where; $e_{i,t}$ is the exchange rate for country i at time t; $i_{i,t}$ is the short-term interest rate for country i at time t; $r_{i,t}$ is the level of reserve assets for country i at time t; and α, β, γ are the weights of the variance of each component: for example $\alpha = 1/\sigma_e$ where σ_e is the standard deviation of exchange rate changes. Subscript 0 stands for the anchor country variables.

These construction forms are the basic indices that have been used in the studies. However, the literature also suggests several other forms. The existence of several approaches seems to suggest that the results gained for the EMP might differ. In addition, it may mean that index choice needs to depend on the features of the individual country; such as, whether it is a developed or developing country, and whether it has free capital movement and a floating or fixed exchange rate. That is why this article also gives other options. Another version offered by Eichengreen et al. (1995, 1996) and Pontines and Siregar (2008) is:

$$EMP_{i,t} = \frac{1}{\sigma_e}\frac{\Delta e_{i,t}}{e_{i,t}} - \frac{1}{\sigma_r}\left(\frac{\Delta rm_{i,t}}{rm_{i,t}} - \frac{\Delta rm_{0,t}}{rm_{0,t}}\right) + \frac{1}{\sigma_i}\left(\Delta(i_{i,t} - i_{0,t})\right), \quad (3)$$

where; $e_{i,t}$ is the units of country i's currency per anchor country's currency in period t; σ_e is the standard deviation of the relative change in the exchange rate; $rm_{i,t}$ is the ratio of gross foreign reserves to money stock for country i in period t; $rm_{0,t}$ is the ratio of gross foreign reserves to money stock for the anchor country in period t; σ_r is the standard deviation of the difference between the relative changes in the ratio of foreign reserves and the money base in country i and the anchor country; $i_{i,t}$ is the nominal interest rate for country i in period t; $i_{0,t}$ is the nominal interest rate for the anchor country in period t; and σ_i is the standard deviation of the nominal interest rate differential between country i and the anchor country.

As can be seen from this, the main question seems to be the weighting of each variable. It is easy to understand that during turbulent times the volatilities or changes in the variables are also higher than in tranquil times. The increased volatilities may result in the overestimation of some variables and may thus result in an estimation bias for the EMP. That is why various authors have tried to adjust the index.

The EMP index can be used to define the moments when there is a crisis in a country. For researchers, the EMP offers further interest because it allows a crisis to be defined as a binary variable and therefore helps in conducting probability based tests.

A country is believed to be in crisis if the index value is higher than an extreme threshold that is often set at 1.5 or more standard deviations of the index. In this case, we can find the depreciation of the exchange rate (Eichengreen et al., 1996):

$$crisis_{i,t} = 1 \text{ if } EMP_{i,t} > \mu_{EMP} + 1.5\sigma_{EMP}, \quad (4)$$
$$\text{otherwise, } crisis_{i,t} = 0,$$

where; μ_{EMP} is the sample mean and σ_{EMP} the sample standard deviation.

If the EMP index is made into a binary variable, it could be used to test how different variables affect the probability of the country being in crisis. Furthermore, it also permits testing for whether the probability of a crisis happening is affected by a crisis elsewhere. If it increases the probability, the null hypothesis needs to be rejected and there is evidence of

contagion. To test the pair, a binary probit model is used (Eichengreen et al., 1996).

In this way the EMP index helps researchers to define crisis moments more objectively and thus lowers the level of subjectivity. The construction of the EMP index depends on the exchange rate regime and the weighting scheme selected for each index component that the researcher decides to use.

3.2. Construction of the Money Market Pressure Index

The previous sections covered the problems of identifying currency crises. However, the nature of recent crises has been much more connected to financial markets. The problem remains that there are no good objective proxies for defining the period of crisis.

In order to capture crises that are defined by excessive demand for liquidity in the market, Hagen and Ho (2007) constructed the money market pressure index. The index is based on the idea that a money market crisis can be measured by both the quantity of excess liquidity available for the banking system, or the lack of liquidity in the system, and the price of the liquidity.

The index follows the exchange market pressure index model in many ways. More precisely, they define a banking crisis as an unusually high demand for liquidity in money markets.

The market is in equilibrium if the demand for reserves is equal to the supply. Depending on the target of the central bank, the disequilibrium could be solved by changing the supply of reserves or by changing the interest rate. If the banks need to increase their liquidity due to losses of assets or due to bank runs, the demand for reserves increases and there is a shift of the demand curve to the right. The new equilibrium, if the supply remains constant, will have a higher interbank rate. If the central bank aims to control the interest rates, the supply needs to increase. This could be done through open market operations or through discount window lending (Hagen and Ho, 2007).

Therefore, the crisis creates a liquidity shortage, and deposit money banks try to get additional reserves from the interbank market or from central banks. In a simplified way the IMP could then be expressed as (Hagen and Ho, 2007):

$$IMP = \Delta f + \Delta i^r , \tag{5}$$

where Δf is the ratio of central bank funds to bank deposits[1]; and Δi^r is the money market rate in real terms.

It is clear that the volatilities of each component could have a serious impact on the index and therefore an adjustment of the components' standard deviations is suggested by changing the index into a weighted sum:

$$IMP = \frac{\Delta f}{\sigma_f} + \frac{\Delta i^r}{\sigma_{i^r}} , \tag{6}$$

[1] The central bank funds to bank deposits ratio is defined as loans from monetary authorities to deposit money banks divided by the total deposits of non-banks with deposit money banks, or total credit support from the monetary authority divided by total bank deposits (Hagen and Ho, 2007)

where; σ_f and σ_{ir} stand for the standard deviation of the central bank funds/bank deposits ratio and real money market rate respectively.

Following Eichengreen et al. (1996), the IMP could also be transformed into a binary variable showing the crisis:

$$crisis_{i,t} = 1 \text{ if } IMP_{i,t} > \mu_{IMP} + 1.5\sigma_{IMP} \ , \quad (7)$$
$$\text{otherwise, } crisis_{i,t} = 0 \ ,$$

where μ_{IMP} is the sample mean and σ_{IMP} the sample standard deviation.

Following this logic, a crisis can be observed in an objective way. With the help of IMP, it is possible to test whether the crisis that is believed to have started at the end of 2007 could also be witnessed in the IMP dynamics.

4. The EMP and IMP in Central Europe

Although the current crisis does not seem to have ended yet, the period is worth closer observation and study. The current crisis is defined by increased volatility and a great drawdown in stock markets. However, the exchange market and money market changes need to be studied as well.

We study the dynamics of these two indices for Hungary, the Czech Republic and Poland. It is expected that the crisis observations calculated using the EMP and IMP indices for the countries studied are not randomly distributed, making it possible to define several crisis moments with the EMP and IMP for the period 2007-2009. The next sections discuss the approach which has been used in this paper to construct our dependent variables for the EMP and IMP.

4.1. Data

Data is taken from the CD-Rom version of the International Monetary Fund's statistics (IFS, 2009). We have used monthly data from 2001M2 through to 2009M9. All the countries had free floating or managed floating exchange rate regimes during the observation period. It is important to stress that our data on countries have time series of different lengths. It has been especially difficult to find the required data for Poland.

Several problems occurred during the data gathering process. We used monthly data in order to increase the number of observations, and because the changes in the exchange market and money market were quite fast, which would have been concealed if we had used quarterly or annual data. However, some data are not available for as long a period as might be wished. The list of variables is included in the Appendices, and the majority of variables are transformed into 12-month changes.

Another problem is that the choice of interest rate could be crucial for this kind of analysis, and it is known that the central banks tried to soften the impact of the recent crisis by lowering official rates. However, the interbank rates have often moved in the opposite direction, so here, we have used the money market interest rates where available, taken from the interbank market.

4.2. The EMP Index

For our study here, we calculate the variable EMP as follows:

$$EMP_{i,t} = \alpha\Delta\ln e_{i,t} + \beta\Delta\ln I_{i,t} - \gamma\Delta\ln r_{i,t} \ , \qquad (8)$$

where e denotes the price of a USD in country i's currency at time t; I denotes country i's money market rate at time t; r denotes country i's international reserves in USD at time t; $\Delta\ln$ stands for change in the natural logarithm of the variables.

α, β, γ are weights that are inverses of the standard deviations of the corresponding variable:

$$\alpha = \frac{1}{\sigma_{\Delta\ln e_{i,t}}} \ ; \beta = \frac{1}{\sigma_{\Delta\ln I_{i,t}}} \ ; \gamma = \frac{1}{\sigma_{\Delta\ln r_{i,t}}} \ .$$

This approach follows the forms used by Jayaraman and Choong (2008) and Bird and Mandilaras (2006); the weights are calculated similarly in Eichengreen et al. (1996).

There are several reasons for this approach. One is that by using this form, we have been able to ensure that the EMP and IMP are calculated in the same manner. On top of this, although several studies have excluded interest rates, we believe that changes in the money market interest rate played an important role in the recent crisis, if not a leading role, and thus should be included in the analysis. Furthermore, one of the underlying models developed by Weymark (1995) excluded interest rates from the analysis on the grounds that there is perfect capital mobility and substitutability between countries. It is arguable whether this is true for the countries studied in this paper. That is why our approach is based more on the Girton-Roper model (1977) and has more similarities with the works of Eichengreen et al. (1996), Bird and Mandilaras (2006); Jayaraman and Choong (2008).

As has been seen already, different scaling schemes are suggested in the literature. We acknowledge the problems connected with the choice of scaling factors, but still prefer the simple scaling factor used in Eichengreen et al. (1996).

Bertoli et al. (2006) point out that different variables and different aggregation methods can lead to different levels of EMP, and therefore the results of the analysis depends substantially on the method used in the construction of the indexes. In order to minimise the potential distortion coming form this source, we decided to use data from one source, (even if this means accepting a shorter sample for Poland), and also to adopt the most standard aggregation approach. As pointed out by Bertoli et al. (2006), the problem arising from indexes construction are relevant when countries investigated have different structure from the OECD one (for which the index was constructed) and/or there are structural changes on the economies in the sample considered. The three CEE countries analysed here have not suffered major structural changes during the sample period, and are also similar to each other; therefore different assumptions would not lead to substantially different results.

This framework should fit better for countries that are more prone to speculative attacks, and we find that this is the case for these three countries. The data have shown that the three countries under investigation here had already experienced some pressure before 2008. Thus the rates of increase in the money market rates increase in the exchange rate expressing depreciation of the exchange rate, and fall in international reserves would all increase in the EMP value.

4.3. The IMP Index

In the construction of the IMP index, two different determinants of the banking crisis are highlighted. The first is based on the amount of excess liquidity and the second on the price of liquidity. During the last financial crisis, both dimensions have had a role in the surge, dynamic and solution of the problem, and therefore the choice of the right variables in constructing the index is extremely important. In order to understand which variables could potentially be able to capture the behaviour of money markets and the banking system, the financial stability reports of the three central banks have been analysed.

From the discussion in Section 3.2, the IMP index (variable *IMP)* used in our paper is the combination of changes in the ratio of central banks funds to bank deposits, and of money market interest rates, weighted by their standard deviations:

$$IMP_{i,t} = \frac{\Delta \ln f_{i,t}}{\sigma_{\Delta \ln f_{i,t}}} + \frac{\Delta \ln I_{i,t}}{\sigma_{\Delta \ln I_{i,t}}} \qquad (9)$$

Where f denotes the ratio of central bank funds to bank deposits for country i at time t; I denotes country i's money market rate at time t; $\Delta \ln$ stands for the change in the natural logarithm.

As has been seen, we have also used the interbank rate in the IMP construction, as we believe it has played a crucial role during the recent crisis.

The quantity of liquidity is tricky to measure. Not only are the interbank money markets different in the three countries, but also the open market operations and the role of the forex exchange market (both spot and forward) are different.

4.4. Dynamics of Indices

The top half of Figure 1 depicts the *EMP* variables and the bottom half the *IMP* variables for the three countries for the period between 2001 and 2009. Figure 3 shows the annual changes in the same indicators for the same countries (*EMP12* and *IMP12*) and for a slightly shorter sample period, as the first year's observations are missing. As explained above, the sample is much shorter for Poland.

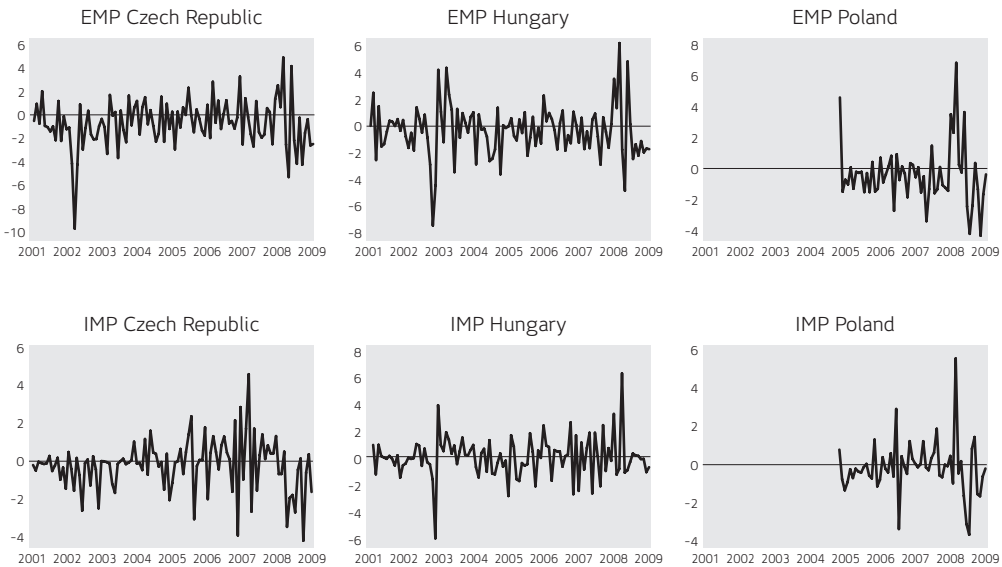
A quick glance shows that between summer 2007 and autumn 2008 both variables reach their peak for the sample considered here, and this is true for all the countries and both indicators. The timing of the arrival of the crisis is different for the three countries, but none of them remains untouched.

Looking more closely, it is possible to see that the jump in the value of the indicators is bigger for Poland and Hungary than it is for the Czech Republic. This is particularly clear for the EMP indicator. This suggests that pressure on the exchange rate of the Czech Koruna has been lower than the pressure on the other two currencies. This hypothesis can also be verified by analysing the monthly and annual changes in the nominal exchange rates of the three currencies. During the sample used here, the Koruna has experienced less sizeable depreciation than have the other two currencies. Taking a depreciation of 3% in a month as a threshold, the Koruna has suffered strong monthly depreciation on six occasions, and only once before the recent crisis, in July 2002. The Hungarian Forint has also weakened six times, but in three different periods (2003, 2006 and 2008-9), and the Polish Zloty 17 times, with an example occurring in every year between 2002 and 2009,

with the exception of 2007[2].

The bottom part of Figure 1 describes the interest rate channel involvement in the transmission of the crisis for the three countries. A difference between the countries that may be noticed is that while Hungary and Poland are hit in September 2008, at the same time as the Lehman Brothers default, for the Czech Republic the IMP peaked earlier, in the second half of 2007 during the first wave of the turbulence in the financial markets in connection with the sub-prime problem.

Figure 1. EMP and IMP for the Czech Republic, Hungary and Poland



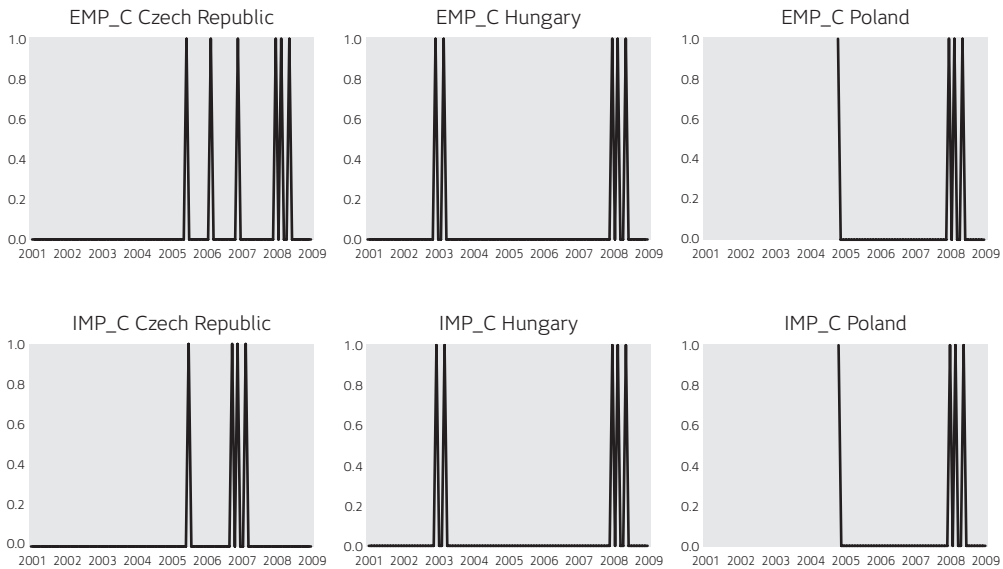
Source: Authors' calculations

One possible explanation for this difference lies in the different interest rates and banking sector structures of the three countries. In the Czech Republic both official interest rates, set by the central bank, and the interbank money market were very low in 2007 before the first wave of the crisis. At the start of the crisis they quickly reacted by increasing rates in summer 2007, while Hungary and Poland already had high interest rates; as they were less linked to the Western European interest rate environment. The second wave of the crisis had more influence on the banking sector, which was more exposed to external financing in Poland and Hungary than in the Czech Republic. The Polish and Hungarian central banks had to intervene to help their local banking sectors, expanding the central bank balance sheets, which have a direct impact on the measurement of the IMP. The intervention in the Czech Republic was not so heavy, given a much healthier situation in the banking sector (CNB, 2009).

[2] A similar message comes considering monthly year-over-year changes: the Koruna had only two months with year-over-year depreciation of more than 10%, both of them in 2009, while the Forint had 14 months with such a depreciation, in 2003, 2006 and during the recent crisis, while the Zloty had 26 months, in 2003, 2004 and during the recent crisis.

Another method has been used to assess the importance of the change in the IMP and EMP indicators. It is possible to measure a threshold above which the value of the indicator becomes significant, so that values above the threshold signal increasing pressure. Those moments are given a value of one, while observations below the threshold are given a value of zero (see Eichengreen et al. 1996 for details). In this way, the binary series of pressure/no pressure can be built (variables *EMP_C* and *IMP_C*). The graphs for these series are presented in Figure 2. These graphs confirm that both indicators show that the crisis affected the three countries in 2008, the only exception being the IMP for the Czech Republic, where the pressure appears in 2007, but not in 2008.

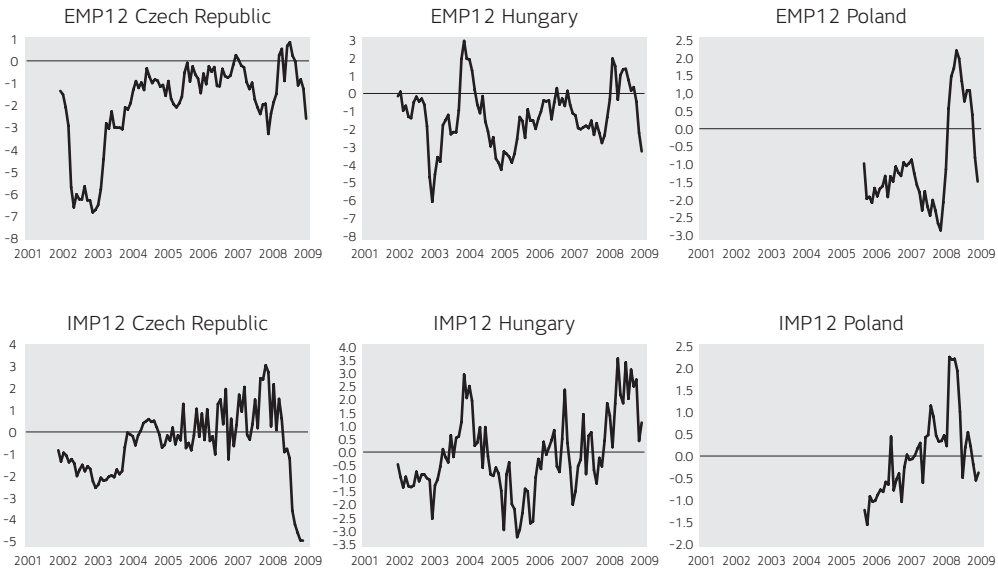
Figure 2. EMP and IMP for the Czech Republic, Hungary and Poland



Source: Authors' calculations

From the presentation in Figure 3 of the *EMP12* and *IMP12* indices, it can be seen that these indicators are stickier than their correspondents for monthly changes. Again, there is an important difference between the Czech Republic on one side and Poland and Hungary on the other. Here, the build up in the pressure measured by both *EMP12* and *IMP12* is slower for the Czech Republic, while it is quite sharp in 2008 for the other two economies. This is particularly true for the exchange rate channel, where the peak of September 2008 is not much higher than the level of the index in the period 2005-2007, while in Hungary, and even more so in Poland, the difference between the highest point of 2008 and the levels in 2005-2007 is much more pronounced.

Figure 3. EMP12 and IMP12 for the Czech Republic, Hungary and Poland



Source: Authors' calculations

It is also noticeable that these indicators show that the pressure on both the Forint and the money market in Hungary is similar in 2008 and in 2003-4, signalling that this market was more subject to external pressure even before the recent financial crisis, in comparison to the Czech Republic. For Poland the data span does not reach out before 2005.

5. Empirical Analysis

5.1. Variables

Our EMP and IMP indices express the present situation of the exchange and money markets while our explanatory variables show the dynamics of the variables in the past 12 months. We run several tests and regression equations over a set of fundamental variables to explain the changes in the EMP and IMP indices. We have been supported in our choice of variables by the theoretical literature and by empirical studies, and also by the reports of the central banks about financial stability.

We have included several variables to consider the generation of the models dealing with the existence of the crises. These variables can be clustered into four groups as banking sector variables, real economy related variables, fiscal situation variables and external balance variable. An exact description of the variables can be found in Appendix 1, the table of descriptive statistics is presented below. For each variable the "overall" statistics (all three countries, the entire dataset), the "between" statistics (the variation of the means to each individual country across time periods), and the "within" (the variation of the deviation from the respective mean to each individual country) statistics are reported.

Table 1. Descriptive Statistics

Variable		Mean	Std.dev	Min	Max	Observations
EMP	overall	-0.502	1.969	-9.730	6.806	*N = 263*
	between		0.204	-0.719	-0.332	*n = 3*
	within		1.961	-9.513	6.716	*T-bar = 87.667*
IMP	overall	-0.135	1.402	-5.950	6.067	*N = 262*
	between		0.092	-0.220	-0.038	*n = 3*
	within		1.400	-6.047	5.970	*T-bar = 87.333*
cpi	overall	0.038	0.024	-0.004	0.108	*N = 315*
	between		0.017	0.027	0.057	*n = 3*
	within		0.020	0.003	0.088	*T = 105*
lagm2_res	overall	-0.015	0.174	-0.492	0.494	*N = 240*
	between		0.038	-0.042	0.032	*n = 3*
	within		0.172	-0.465	0.447	*T-bar = 80*
stocks	overall	0.093	0.320	-0.636	0.888	*N = 315*
	between		0.069	0.030	0.166	*n = 3*
	within		0.315	-0.625	0.868	*T = 105*
lagreer	overall	-0.047	3.815	-10.755	13.134	*N = 312*
	between		0.021	-0.072	-0.033	*n = 3*
	within		3.815	-10.731	13.158	*T = 104*
decl_exp	overall	0.108	0.130	-0.250	0.458	*N = 312*
	between		0.026	0.088	0.137	*n = 3*
	within		0.128	-0.239	0.468	*T = 104*
bor3m	overall	0.419	5.270	-11.638	75.667	*N = 279*
	between		0.297	0.163	0.744	*n = 3*
	within		5.265	-11.963	75.342	*T = 93*
banks_for	overall	0.162	0.418	-0.357	1.898	*N = 243*
	between		0.294	0.024	0.551	*n = 3*
	within		0.358	-0.746	1.509	*T-bar = 81*
dom_cred	overall	0.141	0.095	-0.128	0.404	*N = 243*
	between		0.051	0.095	0.196	*n = 3*
	within		0.086	-0.082	0.349	*T-bar = 81*
govt_borr	overall	0.134	0.433	-0.206	2.726	*N = 243*
	between		0.116	0.022	0.253	*n = 3*
	within		0.421	-0.324	2.608	*T-bar = 81*

Source: Authors' calculations

The growth rate of government borrowing (variable *govt_borr*) is a variable that reflects government fiscal policies. The faster the growth rate, the laxer the policy is understood to be. According to the first generation models this may result in pressure in the exchange markets. In Poeck et al. (2007) the variable has been proven to be useful in explaining pressure in the exchange markets.

Three indicators have been included from the banking sector side. Rapid growth in domestic credit (changes in domestic credit, *dom_cred*) leads to booms in financial markets and could theoretically produce imbalances. In Demirgüç-Kunt and Detragiache (1998), the variable has been shown to increase significantly the probability of a crisis.

It is also important whether the private sector credit growth is funded by domestic or foreign capital (Komulainen and Lukkarila, 2003). To capture this mismatch between the banks balance sheets and foreign funding, the ratio of banks foreign liabilities to assets (*banks_for*) has been included in our study. The variable is often connected with the third-generation models of crises as the ratio expresses the vulnerability to sudden withdrawals of foreign capital. The higher the ratio, the higher is the probability of a crisis.

We have also included a variable (*bor3m*) connecting the interbank money market of the three countries under investigation with the euro area money market. The variable measures the difference between the three months local interbank money market rates and the three months Euribor. A higher value of the variable would be a sign of higher tension in the local money markets (compared to the euro area market), therefore a potential increase in our pressure indicators.

The external balance situation of the three countries has been measured through two variables, REER and decline in export. The changes in REER could help in measuring the over and undervaluation of the real exchange rate, as an overvalued exchange rate may lead to devaluation pressure. We have expected the REER to express these imbalances in advance of the crisis shown by the EMP and IMP extreme values, and thus we have used one month lagged values (variable *lagreer*). Similarly to Castell and Dacuycuy (2009), we expect the higher values of REER to increase the values of the indices.

A decline in exports (*decl_exp*) is connected in the literature with the external sector and shows a country's ability to earn foreign currency. Dornbusch et al. (1995) connect the decline in exports with crises as the variable could show that a country has lost its competitiveness. In Radelet and Sachs (1998), the authors argue that the higher the decline, the bigger the problems a country faces in servicing its current account deficit. Castell and Dacuycuy (2009) suggest that a decline might be caused by an overvalued currency and thus a decline in exports could be an important indicator of an upcoming crisis.

In our analysis the economic situation of the countries has been captured by three variables. Inflation (*cpi*), expressed in the consumer price index, is believed to cause higher interest rates that pressure the exchange market. Even though this is often disputed in the literature, the empirical evidence shows that high values for this variable are relevant in explaining the crises (Demirgüç-Kunt and Detragiache, 1998; Eichengreen et al., 1996; Moreno, 1995).

The connection between stock (*stocks*) returns and crises is discussed in many papers. Our main rationale for including the variable was the integration of the foreign exchange markets and financial markets. The changes in the stock markets could help to capture the changes in market sentiments. The market participants may anticipate a crisis in their expectations, meaning that extreme changes in stock returns might help to predict a crisis. Castell and Dacuycuy (2009) have interpreted the relationship between stock returns and crises similarly to our approach. They argue that a decline in asset prices, including stock returns, may be a signal of a loss of confidence in the market, and they also suggest that bubbles in asset prices might precede a crisis. Similarly, asset bubbles connected with high stock returns are shown to precede financial crises in Calomiris and Gorton (1991).

However, as has been seen, the direction of causality between stock returns and crises is not clear. Granger et al. (2000) have found some inconsistent granger causality between the two. Stavárek (2005) did not find any significant relationships between crises and stock returns, while Broome and Morley (2004) showed that stock returns did indeed help to indicate a crisis.

M2/reserve is connected, because as a government borrows the first generation models of crises as M2/reserves growth ratio could express the lax policies of the government. M2/reserves have been found to be a useful indicator for currency crises in several studies and it is expected that the higher ratio increases the EMP/IMP value or the probability of a crisis. We have expected the M2/reserve ratio to express these imbalances in advance of the crisis, and thus we have used one month lagged values (*variable lagm2_res*) (See Calvo and Mendoza, 1996; Demirgüç-Kunt and Detragiache, 1998; Sachs et al., 1996).

The set of variables used here does not imply that other variables could not be included. We did not use, for example, the lending interest rate to deposit rate ratio, in order to avoid over-correlation with the EMP and IMP indices and because of data availability issues. In addition, the possible predictive power of the current account situation has not been included in our analysis, though it has been used in some other studies. We also left out structural variables, even though some country dummies could potentially improve the regression results. The used approach considers the variables as indicators of weakness in the economy. Thus, these variables help to determine the vulnerability but do not show direct cause.

As we are using static analysis, we do admit some problems connected with the approach. We leave aside the question of whether any crisis in the past has any relevance for the occurrence of a crisis in the future, and so the lagged values of the EMP and IMP indices are not included in our analysis.

5.2. Model

In this section, we present the empirical modelling approach used to study the relationship between the variables already presented and the indices of the crises. The index method discussed above has been used to identify the crises. The indices defined help to identify the moments of excessive demand for liquidity in the money market and moments of excess pressure on the exchange rate. Even though several references have used only one country, we have committed to panel data.

We use three approaches. First, we use a panel regression to study the relationship between the variables and the indices of crises, concentrating on the random and fixed effects. Second, we control the relationship between the EMP/IMP as a binary variable and variables with non-linear regression analysis as a panel logit. Third, we tried to distinguish between variables that indicate a growing vulnerability of the economies to exchange rate and interest rate crisis, and variables that move contemporaneously with the crisis indicators (signalling either co-movement or reaction to the crisis).

We have used STATA 9 for the empirical study. In order to verify the results, we run several tests. The panel regression and panel logit regressions are preceded by the poolability tests. The model specification is controlled by two approaches; by a one by one regression of variables and by the general to specific procedure. Unlike the majority of other studies, we have chosen to use both these indices as level and as binary variables.

Our regression models for the EMP and IMP indices are hybrids of Poeck at al. (2007);

Jayaraman and Choong (2008); Castell and Dacuycuy (2009); Bird and Mandilaras (2006) and Hagen and Ho (2007) for the IMP, in which we compromise several of the previously discussed variables. We focus our attention on the banking sector, the real economy, fiscal situation variables and the external balance. These may be presented in the following models that express that the indices are connected to the variables:

$$EMP = f(cpi, lagm2\_res, stocks, lagreer, decl\_exp, bor3m, banks\_for, dom\_cred, govt\_borr)$$
$$IMP = f(cpi, lagm2\_res, stocks, lagreer, decl\_exp, bor3m, banks\_for, dom\_cred, govt\_borr) \quad (10)$$

We have also used the non-linear approach in the model for the binary crises indices. We use the index of money market pressure and the exchange market pressure index to identify the threshold values, which are later employed in compiling a binary variable of crisis/ no crisis. Similar methods, sometimes as a probit, have been used in Hagen and Ho (2007); Eichengreen et al. (1996); Bussière (2007); Komulainen and Lukkarila (2003). This can be summed up in the following models:

$$EMP\_C = f(cpi, lagm2\_res, stocks, lagreer, decl\_exp, bor3m, banks\_for, dom\_cred, govt\_borr)$$
$$IMP\_C = f(cpi, lagm2\_res, stocks, lagreer, decl\_exp, bor3m, banks\_for, dom\_cred, govt\_borr) \quad (11)$$

The panel logit models for fixed and random effects have been used. These two approaches, panel regression and binary variable analysis, are the methods most commonly used in the literature. However, there are also critical reviews (see Pontines and Siregar, 2008; Li et al., 2006; Bertoli et al., 2006). In our analysis, we have to consider that the time span is not balanced and is critically short for Poland. Episodes with extremely high vales of the EMP and IMP are good for identifying turbulent periods, but the relationship between the variables is not clear.

In Section 5.4, some of the variables will be lagged by one year. The choice of the variables to lag will be explained in that section. We will run the following panel regression with random effects:

$$EMP = f(lag\_cpi\_12, lag\_m2\_res\_12, stocks, lag\_reer\_12, lag\_decl\_exp\_12, bor3m, banks\_for, dom\_cred, lag\_govt\_borr\_12)$$
$$IMP = f(lag\_cpi\_12, lag\_m2\_res\_12, stocks, lag\_reer\_12, lag\_decl\_exp\_12, bor3m, banks\_for, dom\_cred, lag\_govt\_borr\_12) \quad (12)$$

5.3. Regressions Results

Having analysed the poolability of our dataset (see Appendix 3), we may now proceed with the panel regressions. We start with the EMP and IMP indices and then in the later part of this section we look at the binary dependent variables and the probit models.

Table 2 gives the results of the panel regression of the EMP on the left of the table and the IMP on the right of the table for the independent variables described in Section 5.1. The table gives the results of regressions under both hypotheses of fixed and random effects. Given that in theory we do not have any preference between random and fixed effects, we decided to run both the regressions in order to compare the results; this also works for the robustness check. The comparison between the size, sign and significance of the parameters suggest

that they are very similar for the two models, suggesting that our estimate for the model specification is robust.

Starting with the EMP regressions, we found that two groups of variables have significant coefficients. The first is the government-borrowing variable, which has a negative sign. In theory, a government with increasing financing needs will use foreign markets to raise money, and this is potentially negative for the domestic currency; so therefore, the sign should be positive. If we look at what happened during the recent crisis, the dynamic has been different. More precisely, the main channel through which the crisis reached the countries under investigation here has been the financial, especially the banking, sector. The size of the fiscal reaction has been relevant; as it came about in order to help banks in difficulties and as a more traditional expansionary policy to sustain aggregate demand. The fiscal interventions have helped to tame the severity of the crisis, thus driving down the EMP indicator; during the recent crisis, the causality has been from crisis to budget deficits, not vice versa. The causality issue will be addressed in Section 5.4. For the IMP, the sign of the government-borrowing coefficient is also negative, even if it is not significant.

Table 2. EMP and IMP Regressions

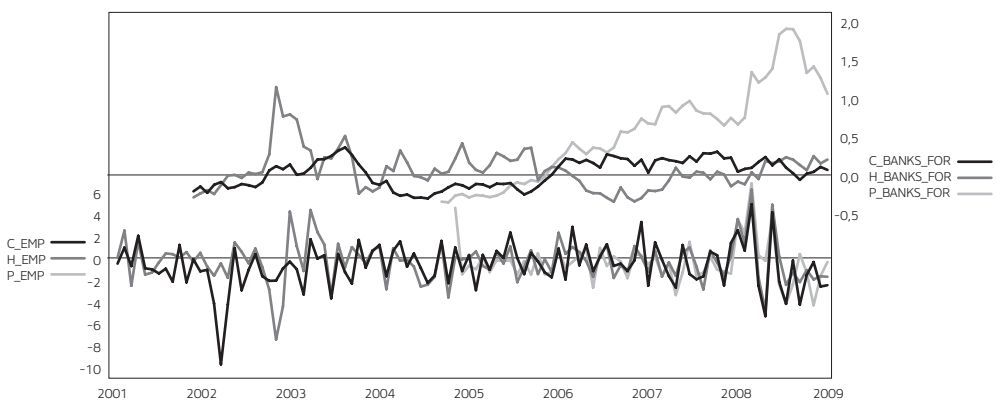
EMP fixed vs random			IMP fixed vs random		
	fixed	random		fixed	random
cpi	-4.187	-10.142	*cpi*	6.718	4.369
	(9.098)	(6.944)		(7.164)	(5.453)
lagm2_res	-2.904 ***	-2.678 ***	*lagm2_res*	-0.728	-0.640
	(0.841)	(0.811)		(0.662)	(0.637)
stocks	0.310	0.215	*stocks*	-0.141	-0.165
	(0.572)	(0.565)		(0.450)	(0.444)
lagreer	-0.064	-0.086 *	*lagreer*	0.004	-0.003
	(0.044)	(0.040)		(0.035)	(0.031)
decl_exp	-2.760	-2.330	*decl_exp*	1.378	1.488
	(1.449)	(1.403)		(1.141)	(1.102)
bor3m	0.040	0.040	*bor3m*	0.003	0.004
	(0.022)	(0.022)		(0.017)	(0.017)
banks_for	-2.161 ***	-1.887 ***	*banks_for*	-0.292	-0.235
	(0.553)	(0.502)		(0.435)	(0.394)
dom_cred	12.368 ***	12.053 ***	*dom_cred*	1.752	1.602
	(2.609)	(2.579)		(2.054)	(2.026)
govt_borr	-1.093 **	-1.084 **	*govt_borr*	-0.253	-0.238
	(0.350)	(0.347)		(0.276)	(0.273)
_cons	-1.500 ***	-1.308 ***	*_cons*	-0.651	-0.562
	(0.446)	(0.387)		(0.352)	(0.304)
N	236	236	N	236	236
R^2	0.19		R^2	0.041	

Note: * p < 0.05; ** p < 0.01; *** p < 0.001
Source: Authors' calculations

The importance of the financial sector in the dynamics of the crisis is confirmed by the significance of the domestic credit variable. Here the sign is positive, as expected: excess growth in borrowing by the private sector can cause a potential threat to the domestic currency and show the potential problems ahead. This is also true for the IMP indicator, even if again the coefficient is not significant.

In addition, another variable linked to the financial sector is significant. The ratio between the foreign liabilities and foreign assets of the banking sector enters the regression with a negative sign. As with government borrowing, here the negative sign indicates that when the crisis finally broke, after a period of stable values of the EMP and a growing level of foreign liabilities relative to assets for the banking sector, banks were suddenly not able to finance themselves in the international markets. The banks switched from the latter financing channel to the local, mainly central bank, channel (NBP, 2009; MNB, 2009). Therefore, the jump in the crisis indicator corresponded to the sharp decrease in the *banks_for* variable. This point is also illustrated in Figure 4. When the crisis hit, the foreign liabilities of banks dropped in the Czech Republic and remained stable in Poland. Only in Hungary did this ratio increase, probably due to the help received by foreign owners of most of the biggest Hungarian banks. Nevertheless, the *banks_for* ratio also started to fall in Hungary in 2009.[3]

Figure 4. EMP and BANKS_FOR for the Czech Republic, Hungary and Poland



Source: Authors' calculations

Outside the financial and government sector, only one variable has a statistically significant coefficient. The lag value of the ratio between M2 and reserves has a negative impact on the EMP.

The other variables, those linked to the general economic environment and to the external sector, have coefficients that are not significant. From one side, this could suggest that the pressure on the domestic currencies of the three CEE countries analysed here has come through the financial and public sectors rather than from the general economic environment of the countries. On the other side, the reason of insignificance of economic and external sector variables could be linked to the fact that these variables create preconditions for a crisis, which is built during the time and well before the crisis eruption,

[3] In Figure 4, the capital letters C, H and P stand for Czech Republic, Hungary and Poland respectively.

but have no contemporaneous link with the crisis indicators. This issue will be addressed in the next section.

A separate discussion applies to the IMP indicator. The results of the regressions, reported in the right hand side of Table 2, show that almost all the variables are not significant in indicating the IMP level. A possible explanation for the difference in the results between the two indicators is that the IMP is built on two variables, which behave in a way that is difficult to capture with the explanatory variables employed here. The IMP is constructed on market overnight interest rates, which move in line with central bank reference rates, making them quite sticky, and on the ratio between the liabilities of the banking sector to the central banks and the banking sector deposits, which is always quite sticky.

The manifestation of the crisis in the two components of the IMP is usually through a jump, both in interest rates and in the central bank balance sheet. The variables used on the right hand side of the regression are often 12-month changes or growth rates, with a more gradual dynamic, which can be more helpful in explaining the dynamic of the build up of a financial crisis than its abrupt and sudden emergence. This is more consistent with the idea of the IMP indicator.

Now we turn to the binary variables *EMP_C* and *IMP_C*, which have a value of 1 when the level indicators EMP and IMP are above a certain threshold and 0 below that level. The results of the panel logit regressions are presented in Table 3.

The first thing to notice is that the sign of the coefficients does not change if the binary dependent variables are used. The main difference lies in the significance of the coefficients, in particular for *EMP_C*. Unlike in the regressions using the EMP level, in Table 2, the decline in exports is significant in measuring the probability of a crisis. Here again the sign of the coefficient is affected by the causality problem. The recent financial crisis has had a dramatic impact on the international markets, causing at least a temporary sharp drop in international trade, which is expressed as a sharp decline in the exports of the CEE countries. This means that there is a contemporaneous inverse relation between the crisis and the export dynamic in these countries. As before, the IMP regression does not show the coefficients are significant.

Table 3. EMP_C and IMP_C regressions

EMP_C logit			IMP_C logit		
	fixed	random		fixed	random
cpi	-16.983	-17.524	*cpi*	7.876	4.840
lagm2_res	-4.918	-4.429	*lagm2_res*	-0.990	-0.824
stocks	0.694	0.585	*stocks*	-1.304	-1.181
lagreer	-0.233	-0.207 *	*lagreer*	0.118	0.113
decl_exp	-16.000 **	-16.845 ***	*decl_exp*	0.315	-0.145
bor3m	0.037	0.013	*bor3m*	-0.045	-0.055
banks_for	-2.683	-2.908	*banks_for*	-1.189	-1.567
dom_cred	28.456 **	28.321 *	*dom_cred*	11.531	11.662
govt_borr	-3.037	-3.894	*govt_borr*	-0.450	-0.422
_cons		-5.606 ***	*_cons*		-4.673 ***

Note: * p < 0.05; ** p < 0.01; *** p < 0.001
Source: Authors' calculations

5.4. Vulnerability versus Direct Effect

One important question that remains unanswered from the estimation of the previous section is how each explanatory variable is related to the market pressure indicators. According to the theory, the general approach used for the majority of studies is that the variables included precede the crisis and therefore help to explain it. However, in this paper, due to the characteristics of the crisis, a difference between the variables used can be made. Some indicate the vulnerability of the economy and the financial sector, which increases the probability of a crisis. Other variables capture the reaction of market participants that is often contemporaneous to the crisis.

In more detail, some variables indicate the emerging weakness of the economy and therefore have a positive relation with the market pressure indices. The influence of these variables is delayed and they enter the analysis with a one year lag. These are typically macroeconomic variables, the changes of which are sticky or that require a long process in order to change.

On the other hand, there are some variables that react in a contemporaneous manner with market pressure indicators, either because they are "price signals" reflecting market sentiment or perception of the actual and future situation of the economy, or because they are under the direct control of economic agents, who can intervene quickly to influence the dynamics of these variables.

This explains our two-group approach where variables are divided into "vulnerability" and "direct impact" variables. The first group includes CPI, M2/reserves, REER and export decline plus government borrowing, which we include in the regression analysis with lagged values. The first two can be read as indicators of growing monetary imbalances, which do not necessarily trigger an immediate reaction in the exchange rates, but increase the probability of the pressure on both the interest rates and the exchange rates. REER and export decline, that is external sector variables signaling the weakening position of a country, seem to have the same lagged effect on the EMP and the IMP. The same implies to the government sector where an increasing debt does not necessarily trigger an immediate reaction in the market but can hinder the confidence of market participants when a high debt level is reached.

The second group includes either "market variables", such as stocks and interest rates (*bor3m*), which describe the market sentiment, or variables that are subject to a sudden stop behavior in case of a crisis, such as domestic credit. Therefore, these variables should react instantaneously compared to the changes in the EMP and the IMP. In fact, both the ability of local banks to collect financial resources abroad and their capacity to extend credit to domestic clients are, similar to financial variables, also dependent on the perception of economic agents, and can therefore reverse their course quickly.

The results of the panel regression with both lagged vulnerability and contemporaneous direct impact variables are reported in Table 4. The results of the grouped variables approach are similar for the IMP, while they offer some new insight for the EMP. First, as concerns the IMP, the ability and willingness of the authorities to control the interest rate channels seems to be confirmed. Furthermore, the EMP regression supports the distinction between vulnerability and direct impact described above.

Comparing the results of Table 4 and Table 2, it is possible to see that the role of the banking sector in the outbreak of the crisis is confirmed (with both *banks_for* and *dom_cred*

remaining significant and with the expected sign).

The role of the government sector in building up the preconditions for a crisis and in attempting to counter the crisis seems clearer now. The effect of government borrowing on the crisis can be twofold. First, as in the previous approaches, increased borrowing enhances the probability of a crisis and is therefore an indicator of vulnerability. On the other hand, it also includes the direct impact, as the government might use expansionary fiscal policies to dampen the effect of a crisis.

The "vulnerability" part of government debt (captured by the coefficient in Table 4) seems to behave as expected (positive, i.e. higher debt indicates higher market pressure), but is not relevant, as its coefficient is not significant. However, the role of a government in helping to counter the direct effect of the crisis appears to be very important, as indicated by the negative and significant coefficient of *govt_borr* variable in Table 2. Therefore, it seems that, at least for the countries analysed here, government behavior has not been a relevant factor in causing the crisis, whereas the expansionary (and debt creating) policies used to counter the crisis have been important and effective.

Table 4. Vulnerability versus Direct Effect Regressions

	EMP	IMP
lag_cpi_12	-13.8248	-9.48848
	(7.349)	(5.970)
lag_m2_res_12	1.49501	0.832092
	(1.067)	(0.867)
stocks	-0.29801	-0.08731
	(0.491)	(0.399)
lag_reer_12	-0.10052 *	0.005018
	(0.048)	(0.039)
lag_decl_exp_12	3.155095 *	-0.22254
	(1.533)	(1.245)
bor3m	0.035934	0.003445
	(0.022)	(0.018)
banks_for	-1.73632 ***	-0.53041
	(0.473)	(0.384)
dom_cred	9.259401 ***	2.320623
	(2.488)	(2.022)
lag_govt_borr_12	0.296046	-0.12139
	(0.372)	(0.302)
_cons	-1.39185 *	0.084158
	(0.559)	(0.454)
N	207	207

Note: * p < 0.05; ** p < 0.01; *** p < 0.001
Source: Authors' calculations

The distinction between vulnerability and direct impact is also relevant for the external sector variables. In particular, export decline becomes significant with the expected (positive) sign, if it enters the equation with a 12-month lagged value. The decline in exports signals the deterioration of the international position of the countries, but the reaction of this variable when the pressure is high is not immediate.

Last, the distinction between vulnerability and direct impact helps to better understand the variables of monetary imbalances. CPI maintains the same sign as the regression in Table 2, but this time the coefficient is "almost significant"[4]. *M2_res* variable is now of the expected sign, signaling that monetary imbalances have indeed played a role in the building of preconditions for a crisis.

5.5. Discussion of the Robustness

We performed different tests in order to check the robustness of our results (see Appendices 2 and 3). First of all, we performed the Hausman test in order to choose the random versus fixed effect specification of our panel estimation. Even if the test shows a preference for the random effect model, we performed the panel estimation with both specification, and the estimated coefficients have the same signs in both estimation, and their size is also similar, which confirm that our model is robust in respect of the estimation specification.

In order to control for the significance of the coefficients, we corrected the standard errors of the coefficients with the Huber-White method, and, with the exception of *bor3m* (as explained above), the significance of coefficients doesn't change.

We also tried a general to specific and a one-to-one estimation procedure in order to see if the insignificance of some of the coefficients depends on possible multicollinearity with other variables. Also in this case, our original results were confirmed.

Finally, we have calculated the indices over the USD, but the calculation over euro did not change the dynamics of the indices. For further research, many questions have risen. It could be possible to continue to study the results depending on the thresholds and window widths used to identify the calculated EMP and IMP indices.

5.6. Discussion of the Results

We conclude this chapter by discussing the main findings of our empirical analysis. The first thing to stress is that the graphical analysis highlights that both the EMP and IMP indices from before 2007 are able to capture the eruption of the global financial crisis in the three CEE countries under investigation here. Both the degree and the timing of the crisis signalled by the indices correspond to the actual emergence of the crisis as reported for example by the analysis of the three countries' central banks.

When the two indices are analysed empirically, the results are not as straightforward as those for the graphical analysis. Firstly, some of the variables used in the empirical analysis turned out to show a significant influence on the exchange market pressure, in particular, domestic credit dynamics and government borrowing, while any link between the money market pressure and the variables employed here seems to be hard to capture. This is more puzzling considering that all the anecdotal evidence suggests that the global financial crisis

[4] Significant at the 10% level.

spread between countries mainly through the banking sector and the interbank money markets.

This puzzle can be explained in our opinion in two ways, the first being more of an economically fundamental reason, the second more of a technical question. From a fundamental point of view, crises find their most evident expression in prices. The three countries analysed here have had a free floating nominal exchange regime[5], during the period under investigation, and therefore crises in these countries have hit the nominal exchange rate immediately, as shown in Figure 5. The figure also shows that the behaviour of the three exchange rates is very similar, making a joint analysis of the three countries easier.

As concerns the IMP index, the interbank interest rate is not controlled directly by the central banks, but is certainly an explicit target of these institutions. The attempt to control this interest rate, which represents the price of short term liquidity, makes the use of this index as a measure of a crisis more complicated. From one side the nature of the interbank markets in general, and of the interaction between the banking sector and the central bank in particular, can differ across countries. In our case, the most explicit example lies in the central banks' monetary policy operations before the crisis. While MNB (Magyar Nemzeti Bank, the central bank of Hungary) usually offered liquidity to the banking sector through monetary policy operations, the other two central banks had almost exclusively withdrawn liquidity from the banking sector before autumn 2008, and turned to liquidity providing operations only at the peak of the crisis. This substantial difference has two main consequences, the first being that aggregating data across the three countries may hinder the explanatory power of the regression of the IMP on the potential explanatory variables.

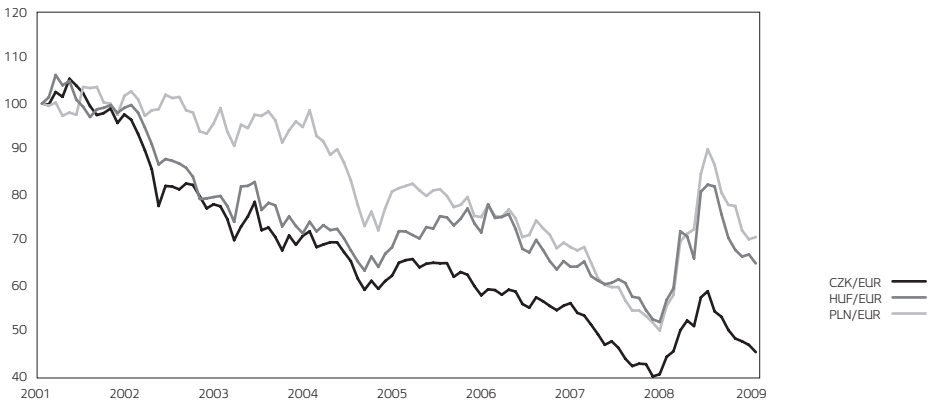
The second, technical, reason for the difference in the empirical analysis between the EMP and IMP is linked to what is explained in the previous paragraph. One of the two components used to build the IMP index is the ratio between CB funding and the deposit size of the banking sector. CB funding was almost not existent in the Czech Republic and Poland before the crisis, while it was always present in Hungary (MNB, 2009; CNB, 2009; NBP, 2009). Also, as explained in chapter 3, the components of the indexes are weighted by their volatility. This means that in the Czech Republic and Poland the CB funding component is underweighted, as it is non-existent for most of the sample, while this is not the case for Hungary. This technical problem can have serious consequences for the construction of the IMP index and therefore also possibly for the results of the empirical analysis. One possible development of our analysis would be a comparison of different weighting schemes for the components of the indexes, but this is outside the scope of our paper.

The difference in the structural liquidity of the banking sectors in the three countries may also be one reason why the money market pressure index used here is difficult to aggregate across countries, and a possible source of insignificance in the pooled regressions. In addition, the possibility of omitted variables should not be overlooked. This is mainly due to the characteristics of recent crises, which involve more panic and less fundamental explanations. As we saw, the existence of crises can also be seen in the exogenous variables used in the analysis, but the arrival of a crisis in the variables is somewhat delayed. A crisis seems to arrive faster in the EMP and IMP indices. Thus, it could be suggested that other

[5] All three countries' central banks have an inflation target as their main policy goal. There was no restriction on the fluctuation of zloty starting from April 2000, while Hungary had an explicit free float regime since 2008, but previously the fluctuation band against the euro was +/-15%, and only once in 2003 Hungary had to intervene in the Forex market at the limit of the band (NBP, 2009; MNB, 2009).

variables are needed to help explain panic triggered crises, rather than the fundamental ones used here.

Figure 5. Hungarian Forint, Polish Zloti and Czech Koruna Nominal Exchange Rate against USD



Note: base = 100 in January 2001
Source: Authors' calculations; IFS.

6. Conclusion

The current paper uses the idea of Girton-Roper (1977) of the exchange market pressure index (EMP) and the money market pressure index (IMP) developed later by Hagen and Ho (2007) to study the relationships between the exchange and money markets and the recent crisis. The analysis focuses on three CEE countries: Poland, the Czech Republic and Hungary. During 2001–2009, financial markets experienced two major shocks: first, the problems emerging from the sub-prime market and later the bankruptcy of Lehman Brothers. These events triggered a reversal of capital flows, a collapse of commodity prices, a loss in confidence, a depreciation of currencies, and a shortage of liquidity.

The EMP index proposes that the exchange market is under pressure if there is excessive demand for foreign reserves during a crisis. This distorts the market equilibrium and the balance should be found through exchange rate depreciation or through other monetary policy measures. The money market pressure index has been developed on the basis of the exchange market pressure index. The IMP index that comprises changes in interest rates and the relationship between central bank funds and bank deposits, suggests that during the crisis, the money market may experience excessive demand for liquidity. The IMP index helps to identify the moments when there is excessive demand for liquidity that causes pressure on the money market. In the IMP, interest rates play an important role as the official rates might move differently from the market rates as seen recently.

Using a similar methodology as Poeck et al. (2007), Jayaraman and Choong (2008), Castell and Dacuycuy (2009), Bird and Mandilaras (2006), and Hagen and Ho (2007), we studied the dynamics of the EMP and IMP during the last nine years and compared their behavior across the three countries. Later, we have used panel regressions over a set of

variables regarding the banking sector, the real economy, the fiscal situation and the external balance to study whether the variables help to determine the vulnerability of the economy to a crisis. We have developed this further by dividing the variables according whether they precede the crisis or evolve simultaneously with it.

In addition, the indices have been employed to define binary dependent variables showing the moments of crisis and no crisis. We have also run panel logit models to see how the explanatory variables influence the probability of the occurrence of a crisis. However, not all the needed data was available for all the countries, especially for Poland, the length of time series is critically short, and thus the panel is not balanced.

Concerning the goal of our analysis to study whether the crisis hit the countries in the same way, it can be concluded that the EMP and IMP indices both manage effectively to capture the turbulent periods. In the studied period of 2001–2009, all countries experienced several moments of high EMP values and the timing of these moments was rather similar. Though none of the countries remains untouched, the pressure on the exchange rate of the Czech koruna has been lower than for the other two currencies.

The dynamics of the IMP index varies more across countries. All countries experienced some moments of higher volatility of the IMP. However, the timing of these periods differs considerably among the three countries. Hungary and Poland were hit in September 2008, simultaneously with the bankruptcy of Lehman Brothers, but the IMP for the Czech Republic already peaked in the second half of 2007, during the turbulence in the financial markets that resulted from the problems of the sub-prime market.

The second objective was to understand what roles the exchange rate and interest channels have played in the transmission of the financial crisis to Poland, Czech Republic and Hungary. It is generally assumed that the crisis spread through the interest rate channels. However, the empirical analysis of the IMP index does not have as clear results as in the case of the EMP index. This can be explained by the vast interventions of the central banks in the money markets and banking sector. All studied Eastern European countries experienced the severest shock from the crisis, as they were very dependent on external funding after lending from foreign banks dried out. Thus, the central banks first seem to have decided to focus on that issue.

The central banks started to cut rates to support the economy and also adopted other monetary measures, such as opening the central bank lending channel to support the financial sector. This had an influence on the behavior of the IMP index.

The measures to help the money market may be considered somewhat exceptional; while as countries remained faithful to traditional FX intervention measures over the crisis, such as the drying out of the FX reserves to control the pace of depreciation and exchange rates, probably also driven by the need to help the real economy. Indeed, the crisis did originate from the money market, but spread freely through the exchange rate channel.

Most importantly, we centered our attention on the factors' changes preceding the crisis and those that played a role in the outbreak of the crisis. It is necessary to distinguish between the variables that first characterise the vulnerability, i.e. the way the economy has built up the preconditions for a crisis, and second, indicators that characterise the reaction of market participants. The majority of previous studies have not included this distinction. The ratio of banks foreign liabilities to assets and domestic credit growth have been identified as the relevant determinants of the impact of the crisis on the EMP index. This is true in panel EMP regression as well as in panel logit analysis. The variables related to the general

economic environment and to the external sectors are relevant in explaining the creation of preconditions for a crisis, i.e. the vulnerability of the countries considered here.

Government borrowing has a minor role in explaining the vulnerability of the countries, but has a relevant role in the outbreak of the crisis. This suggests that the pressure on the domestic currencies of the three CEE countries in question has mainly emerged from the financial sector (but also the external sector and monetary imbalances), while the public sector has played an important part in the reaction to the crisis.

Moreover, the paper examines the role of the authorities in dampening the effects of the crisis. Results show that during the recent crisis the authorities of the three CEE countries concentrated their efforts to reduce the vulnerability of the financial sector. Due to the increased cost and lack of external financing, the central banks acted as liquidity providers. In other words, the central banks intervened to ensure both the operation and the availability of financing in the banking sector. The policymakers used tools that worked for this aim, more specifically for a fast increase in central bank funding at the early stages of the crisis. Much less attention was paid to the exchange rates, since these also worked in favor of the export sector. Our analysis seems to support the hypothesis that the exchange market acted as an absorber of the crisis. Thus, there are differences between the results gained from the EMP and from the IMP.

Several important questions rose for further research. The dynamics of these indices regarding the exchange and money markets need to be studied for other influencing factors, e.g. what, and in which way, has caused these kinds of patterns. The variables employed in this paper cover most of the potential source of instability for the exchange rate and money markets, but not exhaustively. Exploring the influence of other variables on the EMP and IMP indices could add insight on the dynamics and contagion of crises across countries.

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Appendix 1. Data Sources

Indicator	Source	Name in analysis
IMP and EMP indices		
EMP	Nominal exchange rate – IFS line ae International reserves – IFS line 1 L.d Interest rate – Overnight money market rate. Bloomberg	*EMP*
IMP	Ratio of central bank funds to bank deposits – IFS line 24 +line 25+line 26C divided by IFS line 26G Interest rate – Overnight money market rate. Bloomberg	*IMP*
EMP 12-month change		*EMP12*
IMP 12-month change		*IMP12*
Binary variable EMP		*EMP_C*
Binary variable IMP		*IMP_C*
Economy		
Consumer price index	IFS line 64	*cpi* *lag_cpi_12*
M2/reserves ratio growth	IFS line 34+ IFS line 35 converted into dollars using line ae divided by IFS line 1 L.d; 1 month lagged	*lagm2_res* *lag_m2_res_12*
Stock returns	MSCI local stock markets index levels. Bloomberg	*stocks*
External Balance		
REER	IFS line 64; 1 month lagged	*lagreer* *lag_reer_12*
Decline in export	IFS line 70	*decl_exp* *lag_decl_exp_12*
Banking		
localBOR3m-Euribor3m	Difference between local official money market rates (Wibor for Poland, Pribor for the Czech Republic, Bubor for Hungary) and Euribor. Bloomberg	*bor3m*
Net bank foreign liabilities/assets	IFS line 26c divided by IFS line 21	*banks_for*
Changes in domestic credit	IFS line 32, changes compared to previous period	*dom_cred*
Fiscal situation		
Growth rate of government borrowing	IFS line 12a + line 22a	*govt_borr* *lag_govt_borr_12*

Appendix 2. Unit Root and Stationary Tests

	Hungary	Poland	Czech Rep.
EMP	-9.607*	-6.642*	-9.942*
IMP	-13.022*	-7.717*	-4.010*

Note: * no unit root at 1% level
Source: Authors' calculations

For robust results to be obtained from the analysis for the time series, the series should at least be stationary. If the time series are not stationary, some transformation can be used to make them stationary, such as logarithmic returns or first differences.

The standard unit root test is the augmented Dickey–Fuller Test that we have used here. There are no unit roots at 99% confidence level in the EMP and IMP indices for the countries studied according to the Augmented Dickey–Fuller Test.

Appendix 3. Poolability Test

EMP full sample			EMP common sample			
	Hungary	Czech Rep.		Hungary	Poland	Czech Rep.
cpi	-10.850	-13.835	*cpi*	2.811	-62.308	-38.503
lagm2_res	-6.983	-4.831	*lagm2_res*	-6.023	-5.270	-16.194
stocks	-0.540	0.829	*stocks*	1.955	-1.477	-0.430
lagreer	0.000	-0.212	*lagreer*	-0.004	-0.059	-0.105
decl_exp	-5.912	-3.957	*decl_exp*	-6.601	-7.561	-6.232
bor3m	0.094	0.038	*bor3m*	1.968	-0.051	0.048
banks_for	-4.644	-5.251	*banks_for*	-2.983	-1.415	-8.222
dom_cred	25.408	17.683	*dom_cred*	34.657	7.406	30.067
govt_borr	-10.257	-1.428	*govt_borr*	-15.355	2.518	-5.524
_cons	-2.690	-1.688	*_cons*	-4.704	1.155	-1.228
	Value	*F* -stat (5%)			Value	*F* -stat (5%)
F -test	1.573	1.91			1.580	1.83
IMP full sample			IMP common sample			
	Hungary	Czech Rep.		Hungary	Poland	Czech Rep.
cpi	-6.739	11.779	*cpi*	-9.678	-23.981	12.068
lagm2_res	1.280	-0.100	*lagm2_res*	6.802	-6.010	-0.516
stocks	-0.405	0.670	*stocks*	-0.838	1.184	1.228
lagreer	0.023	-0.011	*lagreer*	0.022	0.008	0.076
decl_exp	1.385	3.197	*decl_exp*	1.553	-6.839	4.163
bor3m	0.214	-0.005	*bor3m*	-0.039	-0.117	0.030
banks_for	-0.591	1.300	*banks_for*	0.002	1.635	5.897
dom_cred	-0.040	-0.065	*dom_cred*	-8.429	-3.398	-8.224
govt_borr	1.3328	0.0219	*govt_borr*	0.699	1.041	0.934
_cons	0.260	-0.949	*_cons*	2.125	0.921	-0.306
	Value	*F* -stat (5%)			Value	*F* -stat (5%)
F -test	1.042	1.910			1.217	1.830

Source: Authors' calculations

Before regression, we checked for poolability of the dataset. With an unbalanced panel, the method of checking poolability is not straightforward, and in our case it is particularly difficult because, as mentioned above, for Poland the data range is shorter than for the other two countries. Therefore, we decided to conduct two poolability tests, one for the entire sample and considering only the Czech Republic and Hungary, the other considering all the countries but only for the common part of the sample. (Baltagi, 2005; Park, 2009)

The test is conducted by running regressions (1) and (2), and testing whether the coefficient α_i^j can be assumed to not be different from α_i. The regressions and test have also been run for the IMP.

$$EMP_t = \alpha_0 + \alpha_i X_{i,t} + \varepsilon_t \quad (1)$$

$$EMP_t^j = \alpha_0^j + \alpha_i^j X_{i,t}^j + \varepsilon_t^j \quad (2)$$

The *X* variables are the ones described in section 5.1, and are the ones used in the panel regression, and we have grouped them into four types of variables. The first group of three variables are for the general economic environment: the 12-month change in the consumer price index (*cpi*), the lagged value of the ratio between M2 and central banks' foreign reserves (*lagm2_res*) and the relevant stock exchange 12-month return (*stocks*).

A second group of variables represents the dynamic of the external sector: the lag value of the difference between the REER and its filtered value (*lagreer*), the 12-month change in exports (*decl_exp*) and the difference between the local 3-month interbank markets rate and the corresponding rate in the Euro area (*bor3m)*. The third group of variables is for indicators of the situation in the banking sector: the ratio between the foreign liabilities and foreign assets of the banking sector (*banks_for*) and the 12-month growth of domestic credit (*dom_cred*). Finally, the government sector is represented by the growth of government borrowing (*govt_borr*).

The results of the tests are reported in the table above. In the table, the values of the coefficients are reported, without the *t*-stat values as we are interested for the moment only in the sign of the coefficient, together with the *F*-statistics, which measure the level of statistical difference between the parameters considered in aggregate and estimated with (1) and (2).

Looking at the *F*-statistics, in all four cases the poolability hypothesis can not be rejected at a 5% confidence level. Comparing the single parameters, the message on poolability is not that straightforward, in particular for the IMP index. In the upper part of the table on the left, the coefficients of regression (1) are reported for the full sample of Hungary and the Czech Republic, and eight out of ten have the same sign.

For the shorter common sample, and with the inclusion of Poland, five coefficients have the same sign for all the three countries, as is shown in the upper right part of the table. This can be because in a shorter sample, which also covers the global financial crisis, the parameters can be less stable than when a longer sample is considered. The results for the full sample for Hungary and the Czech Republic corroborate the hypothesis that in the long run the data are poolable across these three countries for the EMP regression.

The regressions using the IMP are dependent variables that give more mixed results. *F*-statistics indicate again that the series are poolable across countries, with 5% confidence, but the signs are different for most of the coefficients. This can be a signal that while market pressure has come through exchange rates in a very similar way in the three countries, the same can not be said for the money market channel.