Exchange Market Pressure in Central Europe: An Application of the Girton-Roper Model

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Abstract

This paper applies the Girton-Roper model of exchange market pressure (EMP) on four Central European economies (Czech Republic, Hungary, Poland, Slovakia) over the period 1995-2008. The results suggest that there is a strong negative relation between domestic credit and EMP in all countries. We also found evidence of positive effect of domestic income on EMP in most of the countries. The paper reveals that EMP in the Czech Republic and Hungary was mostly absorbed by changes of exchange rate while changes in reserves absorbed EMP in Slovakia. The levels of EMP estimated do not pose a significant threat for fulfilment of the exchange rate stability convergence criterion.

JEL Classification numbers: C32; F31; F36

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1. Introduction

In 2004, four countries from the Central Europe (Czech Republic, Hungary, Poland, and Slovakia, hereafter EU4) joined the European Union (EU). As a result, they became official candidates for membership in the euro area. This membership is, however, dependent on fulfilment of several convergence criteria. One of the defined directions of convergence is the convergence and stability of the exchange rate development.

The official criterion requires compulsory participation of the candidate's national currency in the Exchange Rate Mechanism II (ERM II) for at least two years prior to the assessment of the criterion's fulfilment. Moreover, no downward realignment of central parity of the national currency vis-à-vis euro (devaluation) is possible within the two-year evaluation period. Additionally, fulfilment of the criterion requires the exchange rate to have been maintained within a fluctuation margin around the central parity "without severe tensions".

Since the severe tensions are neither explained nor quantified explicitly there is no direct way how to measure and assess tensions on the exchange rate in the context of the convergence criterion. One of the proxies that allow indirect monitoring of the tensions is the exchange market pressure (EMP). EMP is usually related to changes of two cardinal variables describing the external sector of any economy: official international reserve holdings and the nominal exchange rate.

Various concepts of EMP have been developed and empirically tested in literature. Girton and Roper (1977) used a monetary approach to balance of payments and exchange rate determination to derive EMP as simple sum of the rate of change in international reserves and the rate of change in exchange rate. Weymark (1995) revised the original model and introduced a more general approach. Eichengreen et al. (1994, 1995) developed a simpler and model-independent EMP measure.[1]

The current study applies the Girton-Roper (G-R) model on EU4 countries over the period 1995-2008. We consider EU4 countries as apposite examples to test theoretical propositions of the G-R model. This assumption is built on several facts. First, all EU4 countries are small or middle-sized (Poland) economies in which world prices and monetary conditions can be taken as given. Second, all countries followed an exchange rate arrangement of managed or independent floating during the most of the period under estimation. Although many researchers have used the G-R model on different countries[2] the current paper is the first application of the model on countries from Central Europe.

The objective of the paper is twofold. First, we estimate EMP in EU4 countries and assess the EMP development in the context of the exchange rate stability and convergence criterion. Second, we evaluate the suitability and validity of the G-R model for EU4 countries.

The remainder of the paper is organized as follows. Section 2 briefly introduces the concept of the G-R model and derives the equations used in empirical testing. Section 3 deals with data selection and definition and reports the estimation results. Section 4 closes the paper with conclusions.

2. Girton-Roper Model of Exchange Market Pressure

The main theoretical proposition of the G-R model is that the domestic money market equilibrium if disturbed is restored through some combination of the currency depreciation/appreciation and international reserves outflow/inflow. The excess domestic money supply will cause a combination of currency depreciation and reserves outflow while excess domestic money demand will cause some combination of currency appreciation and reserves inflow to restore the money market equilibrium.

This makes the model equivalently applicable in fixed, floating as well as intermediate exchange rate arrangement. In the fixed exchange rate regime, the change of the exchange rate is zero, while in flexible exchange rate regime the change of international reserves is zero. In the intermediate regime (e.g. managed float), the

[1] See e.g. Stavárek (2008) for more detailed discussion on EMP concepts and approaches.
[2] For example, Thornton (1995) on Costa Rica, Mathur (1999) on India, Pentecost et al. (2001) on selected EU countries, Younus (2005) on Bangladesh, de Macedo et al. (2004) on Macau, Parlaktuna (2005) on Turkey, or Khawaja (2007) on Pakistan.

exchange market pressure is absorbed by either currency depreciation, or reserves losses, or a combination of the two.

The G-R model organises the analysis around demand and supply of national monies. The assumptions, explicit and implicit, in G-R model are: Stable demand for money function (money multiplier is held constant), purchasing power parity holds, flow equilibrium in money market and domestic and foreign, interest rates are assumed to grow at equal rate, that is, interest rate differential is held constant.

The demand for money is taken to be stable function of real income (Y_t) and the domestic price level (P_t) given by

$$M_t^d = kP_tY_t \tag{1}$$

where k denotes a constant. The supply of money is specified as the product of the money multiplier (m_t) and the monetary base $(B_t = R_t + DC_t)$, where R_t and DC_t respectively denote net foreign asset holdings and domestic credit creation:

$$M_t^s = m_tB_t \tag{2}$$

The next step is to incorporate into model the assumptions on continuous money-market equilibrium and purchasing power parity relationship:

$$M_t^d = M_t^s \tag{3}$$

$$P_t = E_tP_t^* \tag{4}$$

where E_t is the nominal exchange rate, measured in units of domestic currency for one unit of foreign currency and P_t^* is the foreign price level. Replacing P_t in (1) with $E_tP_t^*$ from (4) and substituting (1) and (2) into (3) leads to (5):

$$kE_tP_t^*Y_t = m_tB_t \tag{5}$$

This equation can also be rewritten as (6):

$$kE_tP_t^*Y_t = m_t(R_t + DC_t) \tag{6}$$

Taking natural logarithms of both sides of the equation

$$\ln k + \ln E_t + \ln P_t^* + \ln Y_t = \ln m_t + \ln (R_t + DC_t) \tag{7}$$

differentiating with respect to time and assuming the constant k yields the following:

$$0 + (\mathrm{d}E_t/\mathrm{d}t)/E_t + (\mathrm{d}P_t^*/\mathrm{d}t)/P_t^* + (\mathrm{d}Y_t/\mathrm{d}t)/Y_t = \\ = (\mathrm{d}m_t/\mathrm{d}t)/m_t + (\mathrm{d}R_t + DC_t/\mathrm{d}t)/(R_t + DC_t) \tag{8}$$

Rearranging (7)

$$(\mathrm{d}R_t/\mathrm{d}t)/(R_t + DC_t) - (\mathrm{d}E_t/\mathrm{d}t)/E_t = \\ = -(\mathrm{d}DC_t/\mathrm{d}t)/(R_t + DC_t) + (\mathrm{d}Y_t/\mathrm{d}t)/Y_t + (\mathrm{d}P_t^*/\mathrm{d}t)/P_t^* - (\mathrm{d}m_t/\mathrm{d}t)/m_t \tag{9}$$

and simplifying (8) by assuming specific letters leads to:

$$r_t - e_t = -d_t + y_t + p_t^* - m_t \tag{10}$$

where r_t and d_t denote ratios of changes in reserves and of domestic credit changes with respect to the monetary base. The remaining variables are growth rates of nominal exchange rate (e_t), domestic income (y_t), foreign prices (p_t^*) and money multiplier (m_t).

The model's intuition is that, for given growth rates of foreign prices and domestic income, increase of domestic credit and/or money multiplier stimulates a proportionate loss in reserves with no change in the exchange rate, or a proportionate depreciation of the domestic currency with no change in reserves, or some combination of these two. On the contrary, an increase in domestic income and/or foreign prices results in a proportional appreciation of domestic currency and inflow of international reserves.

Girton and Roper (1977), Connolly and Silveira (1979), and Bahmani-Oskooee and Shiva (1998) propose to include a variable $q_t = e_t/r_t$ to see whether the monetary authority respond to absorb exchange market pressure either by the exchange rate depreciation or reserves depletion. A significant and positive coefficient of q_t implies that the monetary authority absorb more pressure by the currency depreciation, while a significant and negative q_t implies that more pressure is absorbed by reserves losses. An insignificant coefficient implies that the monetary authority is not sensitive to components of EMP.

$$r_t - e_t = -d_t + y_t + p_t^* - m_t + q_t \tag{11}$$

The coefficient q_t is important in the sense that it allows us to see whether a country follows a traditional monetary approach to balance of payments or exchange rate determination model or G-R model.

3. Data and Estimation Results

A quarterly data from 1995:1 to 2008:1 are employed in the paper yielding 53 observations for each of EU4 countries. The most of the variables were obtained from the IMF's International Financial Statistics and the Eurostat's Economy and Finance database. The missing observations in the time series were replenished from databases accessible on the EU4 central banks' websites. The detailed description of all data series and their sources is presented in Appendix 1.

We applied Augmented Dickey-Fuller (ADF) tests to examine the stationarity of the time series used. According to the character of each time series we tested the stationarity with a linear trend and/or intercept or none of them. The results of ADF tests are reported in Table 1.

The results suggest that all time series are stationary at levels and can be used in regression analysis. We apply the Ordinary Least Squares model on equations (10) and (11). The estimation results are reported in Table 2 and Table 3 individually for each country.

Table 1. Results of ADF tests on time series levels

	emp_t ($r_t + e_t$)	d_t	y_t
Czech Republic	-5.6439*	-4.4890*	-4.3177*
Hungary	-6.1667*	-7.2750*	-2.4028**
Poland	-5.7094*	-9.4160*	-1.9662**
Slovakia	-7.1430*	-7.8224*	-4.1139*
	p_t^*	m_t	q_t
Czech Republic	-2.2774**	-8.0456*	-6.3954*
Hungary	-2.2774**	-9.8658*	-7.1174*
Poland	-2.2774**	-10.972*	-5.3863*
Slovakia	-2.2774**	-11.149*	-5.6811*

*Note: * and ** denote significance at 1 percent and 5 percent level respectively*
Source: Authors' calculations

The tables also contain results of some diagnostic tests. We applied Jarque-Berra (J-B) indicator to assess normality of the residuals distribution, Breusch-Godfrey Lagrange multiplier (LM) to test serial correlation, Lagrange multiplier test for autoregressive conditional heteroscedasticity (ARCH) and White test to check heteroscedasticity of the error term. All LM and ARCH tests were run with four lags. We also applied Ramsey RESET test to check for misspecification of functional form of the model.

Table 2. Model 1: OLS estimation of equation (10)

Czech Republic			**Hungary**		
variable	coefficient	std. error	variable	coefficient	std. error
c	0.0063	0.0069	c	0.0342*	0.0068
d_t	-0.6591*	0.1105	d_t	-0.9829*	0.0441
y_t	0.4139**	0.1614	y_t	0.2291**	0.0929
p_t^*	-0.0727	0.0492	p_t^*	0.0006	0.0437
m_t	-1.1152*	0.1608	m_t	-0.6976*	0.1231
R^2=0.7667, SEE=0.0541, DW=2.4479			R^2=0.9351, SEE=0.0472, DW=1.4471		
J-B=1.7811 (0.4104), LM=2.0336 (0.1226), ARCH=1.1972 (0.3255), WH=28.73 (0.0000), RESET=2.7611 (0.1108)			J-B=2.9571 (0.2279), LM=0.6939 (0.6002), ARCH=0.5644 (0.6897), WH=1.113 (0.3611), RESET=2.9310 (0.0935)		
Poland			**Slovakia**		
variable	coefficient	std. error	variable	coefficient	std. error
c	0.0243*	0.0073	c	0.0143**	0.0076
d_t	-1.0406*	0.0940	d_t	-0.9707*	0.0232
y_t	0.2164*	0.0748	y_t	0.1299	0.1273
p_t^*	-0.1144*	0.0426	p_t^*	-0.0265	0.0399
m_t	-0.9592*	0.1573	m_t	-0.7637*	0.1005
R^2=0.7733, SEE=0.0494, DW=2.0709			R^2=0.9734, SEE=0.0451, DW=1.8489		
J-B=0.4803 (0.7865), LM=0.4616 (0.7634), ARCH=0.8997 (0.4724), WH=2.344 (0.0680), RESET=0.0016 (0.9679)			J-B=0.6626 (0.7179), LM=2.0183 (0.1084), ARCH=1.2856 (0.2902), WH=3.310 (0.0179), RESET=0.0427 (0.8371)		

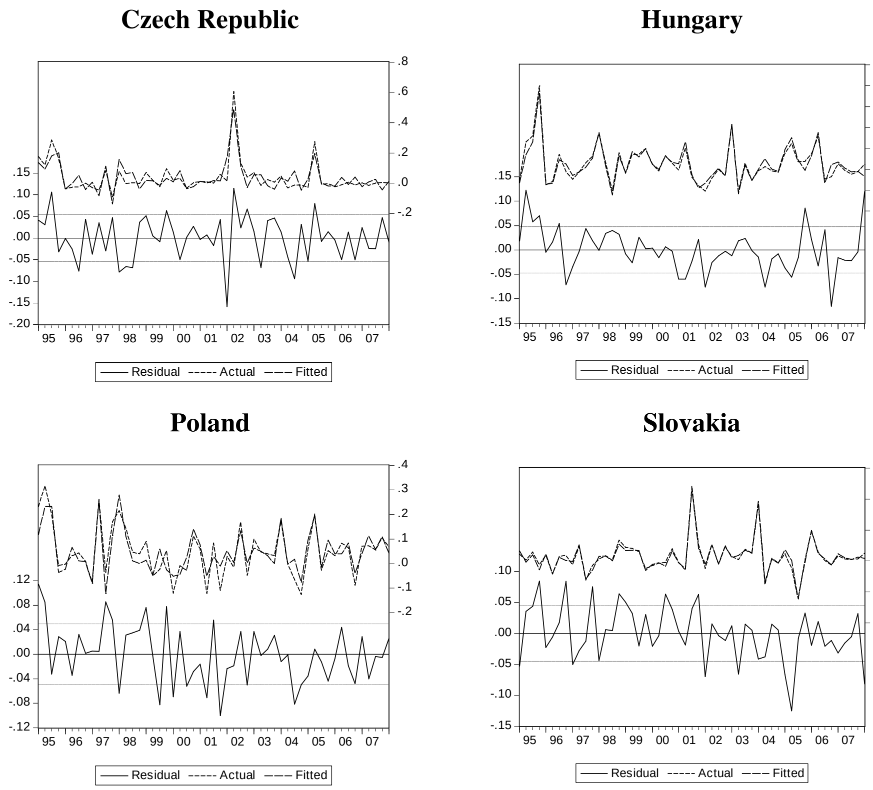
*Note: * and ** denote significance at 1 percent and 5 percent level respectively*
Source: Authors' calculations

Equation (10) represents a simple model of EMP and its estimation leads to generally plausible results. All the models passed most of the diagnostic tests. However, we found evidence of potential heteroscedasticity of residuals in the models of the Czech Republic and Slovakia. Therefore, we corrected the standard errors of parameter estimates by the White procedure. The Ramsey RESET tests confirmed the appropriate functional form of all national models.

As regards to coefficient estimates, growth of domestic credit and change of the money multiplier are significant and correctly signed in all individual models. Thus, it can be stated that expansion of domestic credit and increase of money multiplier result to depletion of reserves and/or depreciation of domestic currency.

Taking the Czech Republic's model estimation as example, the coefficient of domestic credit (-0.6591) implies that a 10% increase in the domestic credit causes the exchange rate to depreciate by 6.591%, or a loss of reserves by 6.591% or a combination of the two of the same extend.

Figure 1. Actual and fitted EMP in Model 1



Source: Authors' calculations

The monetary approach holds that given full employment, the newly created domestic credit is spent on import of goods and services or on acquisition of assets abroad. Since all EU4 countries are open economies with no barriers to international trade or capital movements both channels of spending the domestic credit are possible.

The coefficient of foreign inflation is significant only in Poland having, however, the opposite sign that theory assumes. Therefore, we may conclude that the inflation in the euro area does not affect EMP in EU4. One can consider this as rejection of the condition that purchasing power parity holds. The coefficient of the domestic income growth is significant in three countries. All significant parameters have positive sign, which is in accordance with theory. The growth of domestic income therefore influences EMP through accumulation of reserves or appreciation of domestic currency.

All models have good explanatory power that can be illustrated by comparison of actual and fitted EMP (Figure 1). The models seem to be consistent over the whole estimation period. We performed the Quandt-Andrews test which tests for unknown structural breakpoints in an equation's sample. The null of no structural changes cannot be rejected in any model. The test tend to designate 2002Q1 in the Czech Republic, 1997Q1 in Hungary, 1999Q2 in Poland and 2005Q2 in Slovakia as major though insignificant breakpoints.

Model 2 is based on equation (11) and incorporates the variable q_t that is a ration of change of exchange rate on change of reserves. This explanatory variable is added to realize whether EMP is sensitive to its distribution on foreign exchange and reserve components. The results of estimation of Model 2 are presented in Table 3.

Table 3. Model 2: OLS estimation of equation (11)

Czech Republic			**Hungary**		
variable	coefficient	std. error	variable	coefficient	std. error
c	-0.1971*	0.0422	c	-0.0210	0.0205
d_t	-0.3211*	0.0921	d_t	-0.8798*	0.0621
y_t	0.1961	0.1449	y_t	0.1979**	0.0968
p_t^*	-0.0367	0.0314	p_t^*	0.0039	0.0441
m_t	-0.6029*	0.1170	m_t	-0.6265*	0.1307
q_t	0.2033*	0.0404	q_t	0.0526*	0.0182
R^2=0.8588, SEE=0.0426, DW=1.7930			R^2=0.9399, SEE=0.0460, DW=1.4209		
J-B=3.2173 (0.2001), LM=0.9162 (0.4632), ARCH=0.3652 (0.8321), WH=0.820 (0.5415), RESET=2.4156 (0.1278)			J-B=7.8285 (0.0200), LM=0.8692 (0.4902), ARCH=0.6399 (0.6368), WH=1.373 (0.2515), RESET=0.0098 (0.9215)		
Poland			**Slovakia**		
variable	coefficient	std. error	variable	coefficient	std. error
c	0.0896	0.1580	c	0.0185*	0.0081
d_t	-1.1169*	0.1824	d_t	-0.9776*	0.0164
y_t	0.2222*	0.0763	y_t	0.1188	0.1293
p_t^*	-0.1123**	0.0421	p_t^*	-0.0281	0.0407
m_t	-1.0378*	0.2258	m_t	-0.7648*	0.1009
q_t	-0.0633	0.1545	q_t	-0.0035*	0.0007
R^2=0.7743, SEE=0.0498, DW=2.0299			R^2=0.9742, SEE=0.0449, DW=1.9129		
J-B=0.4034 (0.8173), LM=0.4222 (0.7917), ARCH=0.8187 (0.5203), WH=2.134 (0.0777), RESET=0.0072 (0.9327)			J-B=1.3218 (0.5163), LM=1.6864 (0.1706), ARCH=1.0933 (0.3717), WH=2.835 (0.0256), RESET=0.0516 (0.8213)		

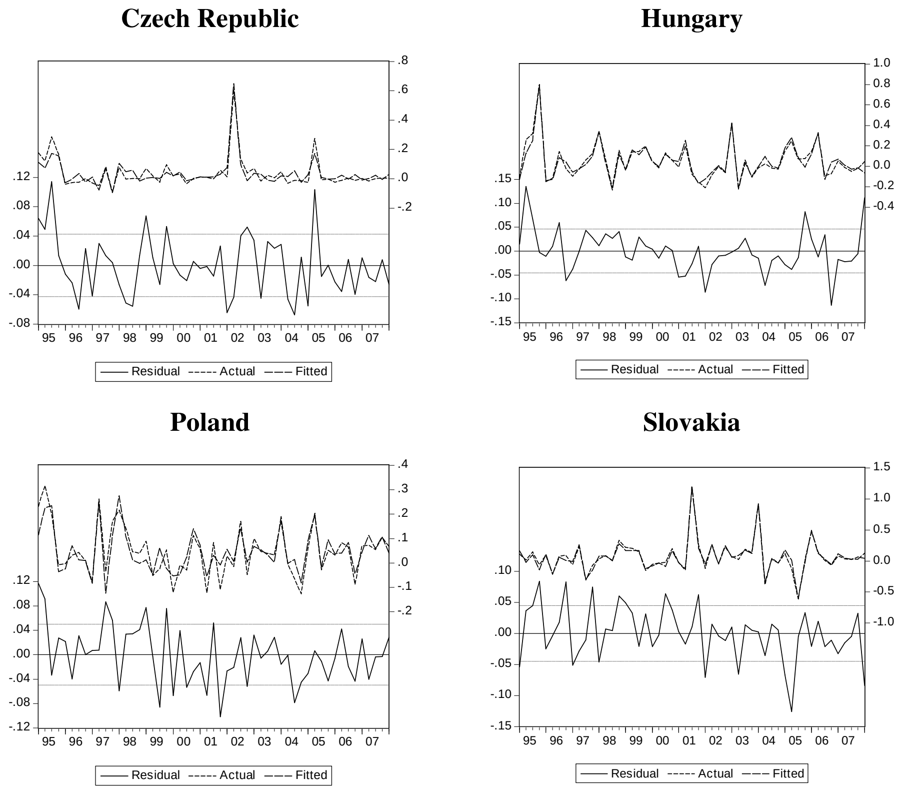
*Note: * and ** denote significance at 1 percent and 5 percent level respectively*
Source: Authors' calculations

The estimated parameters and their significance differ slightly from those of Model 1. The coefficients of domestic credit growth and change of money multiplier are again significantly different from zero and correctly signed in all EU4 countries. Foreign inflation is likely to have insignificant influence on EMP in most of the countries. On the contrary, the growth of domestic income turned out to be significant in Hungary and Poland.

The coefficients of variable q_t are significant at 1% level in all EU4 except for Poland. While positive values of the coefficient in the Czech Republic and Hungary suggest that EMP is absorbed by changes of exchange rate, the negative coefficient in Slovakia indicates that changes in reserves are used to reduce EMP.

With exception of non-normality of residuals in Hungary's model and heteroscedasticity in Slovakia's equation all the models passed the applied diagnostic tests. As compared to Model 1 the explanatory power of Model 2 is noticeably higher only in the Czech Republic. Figure 2 provides a graphical illustration of actual and fitted EMP for all countries. The results of the Quandt-Andrews tests allow us to conclude that there is no evidence of significant structural breakpoints in the equations estimated.[3]

Figure 2. Actual and fitted EMP in Model 2



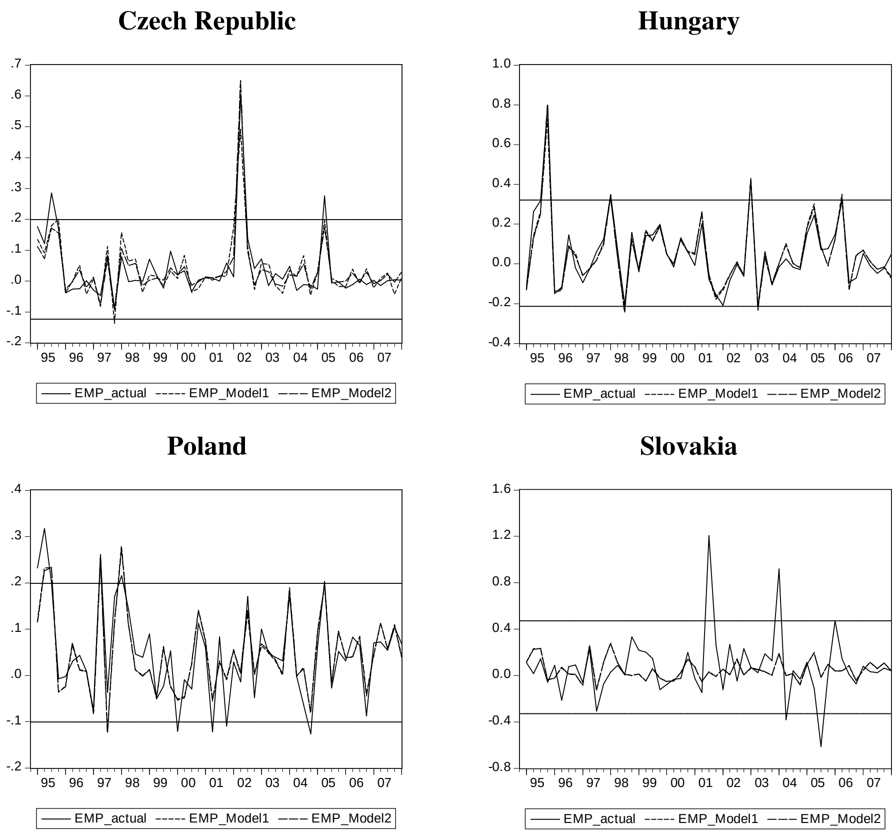
Source: Authors' calculations

[3] The major potential breakpoints were identified identically with Model 1.

We also estimated the models using r_t and e_t as a dependent variable instead of EMP. Estimation of the models with change in reserves on the left side of the equation led to very similar results as compared to Model 1 estimations. The coefficients of domestic credit and money multiplier were always properly signed and significant. We found some differences in sign and significance of the foreign inflation and domestic income parameters. The explanatory power of these alternative models was usually marginally higher than that of Model 1.

The coefficients of explanatory variables from models with change of exchange rate as the dependent variable are mostly insignificant with wrong signs. These findings suggest that EMP in all countries developed almost concurrently with the changes in reserves. It implies a frequent application of the central bank official intervention even in the environment of the floating exchange rate regime. However, the reality in many EU4 was different.

Figure 3. Comparison of actual and fitted EMP from Model 1 and Model 2



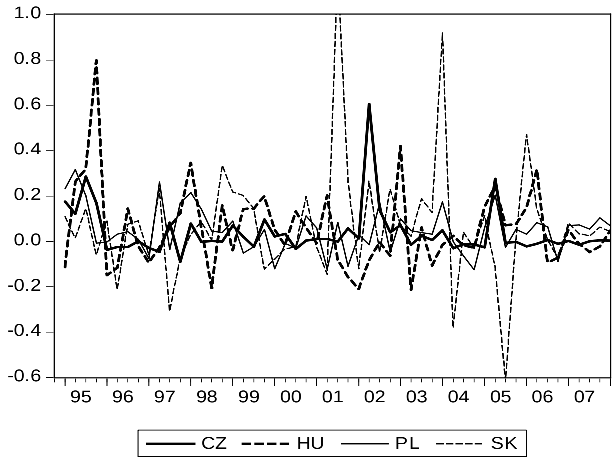
Source: Authors' calculations

One of the paper's objectives is to estimate EMP in EU4 countries and assess the EMP development in the context of the exchange rate stability and convergence criterion. For this purpose Figure 3 depicts development of actual EMP (dependent variable from Model 1 and Model 2) along with fitted EMP calculated according to equations estimated. The developments of actual EMP of all EU4 are also presented jointly in Figure 4.

To evaluate EMP correctly it is necessary to remember some elementary facts. First, a negative value of EMP indicates that the currency is under general pressure to appreciate. On the contrary, positive EMP shows that the currency is pressured to depreciate. Second, the value of EMP represents the magnitude of the foreign exchange market disequilibrium which should be removed by a respective change of the exchange rate.

The graphs in Figure 3 contain, besides the EMP curves, the lines representing 1.5 multiple of the standard deviation above and below the mean actual EMP value. A breach of the corridor is considered as an excessive EMP, alerting to a potential crisis. Such a construction of thresholds has been widely adopted in many studies and has become preferred method to e.g. the extreme value theory (see Pontines and Siregar, 2006).

Figure 4. Comparison of actual EMP in EU4 countries



Source: Authors' calculations

One can find only few features of the EMP development that EU4 countries share in common. All the countries went through periods of higher and more volatile EMP as well as lower and less volatile EMP. However, the timing of these periods differs across the countries.

The first two years of the estimation period were characteristic of quite unstable development resulting in breaching of the corridor's margin in three countries. The period of the most impulsive EMP development can be observed in 2002-2005. During that time, Hungarian forint was under speculative attack which culminated in devaluation of the central parity. The excessive EMP in the Czech Republic reflected the necessity for a correction after the previous long-lasting appreciation of Czech koruna and peaking at the historic high. Some other examples of excessive EMP can be explained by changes of interest rates in EU4 that affected the interest rate differential against the euro area and could have an impact on EMP[4]. However, since interest rates are not included in the G-R model this hypothesis cannot be justified empirically. There is a strong evidence of stabilization of EMP over the last two years in all EU4 countries.

According to width of the corridor denoting the "safe zone" for EMP the most volatile EMP can be found in Slovakia followed by Hungary. Whereas the depreciation pressure prevailed on Czech koruna and Slovak koruna the proportion of appreciation-pressure and depreciation-pressure quarters was more balanced in the case of Hungarian forint and Polish zloty.

The estimated levels of EMP and the recent development suggest that foreign exchange markets in EU4 were free of severe tensions on national currencies in the last years. The EU4 countries that have not joined the euro area will be probably confronted with some occasions of excessive EMP during the participation in ERM II. Nevertheless, these extreme situations are not likely to last for a long time. Thus, they should not jeopardise fulfilment of the exchange rate stability convergence criterion.

4. Conclusion

In this paper, we applied the G-R model of EMP for the EU4 currencies against the euro exchange rate over the period 1995-2008. The main theoretical proposition of the G-R model is that the domestic money market equilibrium if disturbed is restored through some combination of the currency depreciation/appreciation and international reserves outflow/inflow.

We used the ordinary least squares regression analysis for estimation of a series of models. We revealed a statistically significant negative impact of domestic credit increase and money multiplier increase on EMP in all countries. Moreover, a positive relationship between domestic income and EMP was found in three countries. Results of experimenting with modified versions of the G-R model allow us to conclude that EMP in the Czech Republic and Poland was absorbed mainly by changes of the exchange rates. On the contrary, a dominance of changes in reserves in absorbing EMP was revealed in Slovakia.

The paper provides evidence that EU4 countries do not suffer from a long-persisting excessive EMP. Moreover, there was no occasion of excessive pressure in the last two years. Such a conclusion is favourable in the context of fulfilment of the exchange rate stability convergence criterion.

Although all the models estimated have a good explanatory power they do not incorporate interest rates and interest rate differential, which has often been identified as one of the factors of the exchange rate determination in EU4. Therefore, this limitation should be taken into consideration when interpreting the results obtained.

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[4] See e.g. Mirdala (2009) for more on effects of the monetary policy interest rates in EU4 countries.

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Appendix 1

e_t Percentage change of nominal exchange rate. EU4 national currencies vis-à-vis euro in direct quotation (number of EU4 currency units for one euro)
Obtained from Eurostat's Economy and finance database (EEF) section Exchange rates and Interest rates, line Euro/ECU exchange rates – Quarterly data. Logged values.

r_t Proportional change in domestic international reserves. Obtained from IMF's International Financial Statistics. The change in reserves = minus 'financing of the balance of payments' (IFS line 79 dad) deflated by the seasonally adjusted inherited money base (IFS line 14).

d_t Proportional change in domestic credit. Proxied by the percentage change of the seasonally adjusted money base (IFS line 14) minus the proportional change in international reserves (r_t)

y_t Percentage change in domestic income. Obtained from logged values of Gross Domestic Product (IFS line 99B)

p_t^* Percentage change in foreign price level. Eurozone Harmonized indices of consumer prices Obtained from EEF section Prices, line Harmonized indices of consumer prices – Monthly data (index 2005=100). Converted from monthly to quarterly data by averaging the three monthly figures and then logged.

m_t Percentage change of money multiplier. Multiplier calculated as ratio of M2 aggregate on money base. M2 obtained from EU4 central banks' databases and money base from IFS line 14.

q_t Parameter q_t calculated as ratio of percentage change of nominal exchange rate (e_t) and proportional change in international reserves (r_t).