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Comparative Analysis of the Exchange Market Pressure in Central European Countries with the Eurozone Membership Perspective[‡]

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Abstract

This paper estimates the exchange market pressure (EMP) in four Central European countries (Czech Republic, Hungary, Poland, Slovakia) during the period 1993-2006. Therefore, it is one of very few studies focused on this region and the very first paper applying concurrently model-dependent as well as model-independent approach to the EMP estimation on these countries. The results obtained suggest that the approaches are not compatible and lead to absolutely inconsistent findings. They often differ in both identification of principal development trends and estimated magnitude and direction of the pressure. Therefore, any general conclusion on those issues is hard to draw. The paper provides evidence that a shift in the exchange rate regime towards the quasi-fixed ERM II should not lead to increasing EMP. However, it is highly probable that some episodes of the excessive EMP will make the fulfillment of the exchange rate stability criterion more difficult in all countries analyzed unless the criterion will have eased.

Keywords exchange market pressure; model-dependent approach; model-independent approach; EU New Member States; exchange rate stability criterion

JEL classification C32; E42; F31; F36

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1. Introduction

Eight countries from Central and Eastern Europe (hereafter EU8) joined the European Union (hereafter EU) in the spring of 2004 and completed the transformation from centrally planned economies to market economies. Moreover, it is expected that they will also join the Eurozone and implement the euro as their legal tender. However, membership in the Eurozone is conditioned by fulfillment of the Maastricht criteria. One of which is the criterion of the national currency's stability in the period preceding entry into the Eurozone.

This criterion is associated with specific exchange rate regime, ERM II, which must be adapted by all countries with regimes whose principles do not correspond with the ERM II's spirit.[1] It means that all EU8 countries except for Estonia and Lithuania had or will have to modify their exchange rate arrangement when joining ERM II.[2] The Czech Republic, Hungary and Poland currently use flexible exchange rate arrangements. Slovakia and to a lesser extent Slovenia also maintained a flexible regime before entry into the ERM II. Such a change toward a less flexible exchange rate system could increase susceptibility of the countries to currency crises and pressures on the foreign exchange markets.

Therefore, the aim of this paper is to estimate exchange market pressure (EMP) in the Czech Republic, Hungary, Poland and Slovakia (hereafter EU4) during the period 1993-2006. Since all countries applied both a fixed and flexible exchange rate regime, the time span chosen allows us to compare magnitude of tensions on the foreign exchange market in different exchange rate environments. This kind of analysis has important policy implications as Slovakia has already switched to a less flexible regime and the remaining countries will make this unavoidable step is in the near future.

The paper is structured so that Section 2 describes the meaning and theoretical concepts of EMP and provides a review of the relevant literature. In Section 3, the models and data used are cited; Section 4 reports the empirical results and the conclusions are presented in Section 5.

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[1] The group of incompatible regimes includes crawling pegs, free floats or managed floats without a mutually agreed central rate and pegs to anchors other than the euro.

[2] As of 31st December 2006, five of the EU8 (Estonia, Latvia, Lithuania, Slovakia and Slovenia) joined the ERM II. Nevertheless, the exchange rate regime in Latvia was very similar with the ERM II, thus the "costs" of the regime's rearrangement are rather marginal.

2. Exchange Market Pressure and Literature Review

2.1 Meaning and Concepts of the Exchange Market Pressure

The term "exchange market pressure" 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. However, the notion of EMP was more precisely defined, for the first time, in Girton and Roper (1977). In this seminal paper, the authors utilized a simple monetary model of the balance of payments to devise an index of the excess demand for money that must be relieved by either exchange rate or reserve changes to keep the money market, and hence the balance of payments, in equilibrium. The index was the simple sum of the rate of change in international reserves and the rate of change in the exchange rate. For the first time, they termed this index as EMP. However, some shortcomings can be found in the model. Since the measure is derived from a highly restrictive monetary model the formula cannot be applied to other models. Furthermore, a model-dependent definition is used, thus, a unique formula for EMP cannot be identified within the Girton-Roper framework.

The original concept of EMP has been modified and extended by many researchers. For example, Roper and Turnovsky (1980) and Turnovsky (1985) introduced the idea of using a small open-economy model and extended the original model by substituting the simple monetary approach by an IS-LM framework with perfect mobility of capital. They allowed intervention to take the form of changes in domestic credit as well as changes in reserves. The consequence of these modifications was that the EMP was still a linear combination of the rate of change of the exchange rate and money base but these two components were no longer equally weighted as in the Girton-Roper model.

A notable contribution to the EMP theory was provided by Weymark (1995, 1997a, 1997b, 1998). She revised the models mentioned above and introduced a more general framework in which the models are both special cases of the generalized formula. She introduced and estimated a parameter (conversion factor) standing for the relative weight of exchange rate changes and intervention in the EMP index. Since all previous EMP definitions stemmed from a specific model, Weymark also proposed a model-independent definition of EMP as:

> *The exchange rate change that would have been required to remove the excess demand for the currency in the absence of exchange market intervention, given*

the expectations generated by the exchange rate policy actually implemented (Weymark, 1995, p.278)

An extension making the simple model outlined in Weymark (1995) more realistic was introduced in Spolander (1999). He incorporated into the model a monetary policy reaction function and sterilized foreign exchange intervention.

Many researchers have criticized the most undesirable aspect of the EMP measure, dependency on a particular model, and proposed some alternative approaches. A simpler and model-independent EMP measure was originally constructed in Eichengreen et al. (1994, 1995). According to this approach EMP is a linear combination of a relevant interest rate differential, the percentage change in the bilateral exchange rate and the percentage change in foreign exchange reserves. Contrary to Weymark's approach, the weights are to be calculated from sample variances of those three components with no need to estimate any model.

The modified EMP index was introduced in Sachs et al. (1996). This measure consists of the same elements but addresses the question how to weight the three components to avoid the dominance of the most volatile variable. Each weight in the EMP index is calculated with respect to standard deviations of all components included instead of using only standard deviation of the respective component.

The original model by Eichengreen et al. (1996) was modified in Kaminsky et al. (1998) and Kaminsky and Reinhart (1999). The interest rate differential is substituted by relevant interest rate in the country analyzed. Furthermore, the weights on the reserves and interest rate terms are the ratio of the standard error of the percentage change of the exchange rate over the standard error of the percentage change of reserves and the interest rate differential respectively. An approach stemming from Eichengreen et al. (1996) was also followed by Pentecost et al. (2001). However, they determined the weights using principle components analysis.

Because neither the components of the index nor the weighting scheme is derived from a structural model of the economy the EMP indices obtained in Eichengreen et al. (1996), Sachs et al. (1996), Kaminsky et al. (1998), Kaminsky and Reinhart (1999) and Pentecost et al. (2001) are model-independent.

2.2 Review of Relevant Empirical Literature

Since its introduction, EMP has attracted the attention of many researchers and a great number of theoretical as well as empirical papers have been published. The empirical EMP literature is bi-directionally oriented. Whereas some of the papers are directly focused on estimation of EMP in a variety of regions and countries, the second category of studies use the EMP measure as an element of subsequent analysis examining currency crises, monetary policy, foreign exchange intervention, exchange rate regime and other issues. In accordance with the geographical orientation of this paper, only studies empirically analyzing EMP in EU4 are cited in the following literature review.

Although EMP has been a frequently discussed and examined topic in the literature[3] one can find a very limited number of papers focused on new EU Member States and EU4 in particular. Only four consistent studies estimating EMP in all or some of EU4 have been published to date.

The first study estimating EMP in, among others, some of EU4 (Czech Republic and Poland) was Tanner (2002). He applied the traditional Girton-Roper model on data from 32 emerging countries and, consequently, examined the relationship between EMP and monetary policy in a vector autoregression (VAR) system. The aim was to re-examine currency crises in emerging markets in 1990-2000 in a more traditional way by emphasizing the role of monetary policy at or around the time of crisis. Regarding the EMP calculated in the Czech Republic and Poland, they were modest as compared to other countries and very similar to each other. However, EMP in Poland was twelve times higher than in the Czech Republic during the Asian in the second half of the 1990s. Tanner's paper also provided evidence that there was a positive relationship between EMP and domestic money supply in both EU4 countries analyzed but not as significant and straight as in other countries. The only shocks to EMP can help explain monetary policy in Poland, possibly indicating sterilized intervention.

A more specific application of the Tanner (2002) approach is Bielecki (2005). The paper concentrates only on Poland from 1994-2002. The results from the VAR system analyzing the relationship between EMP and changes in domestic credit (monetary policy actions) indicate that domestic credit reacted in a counter direction to innovations to EMP. Furthermore, in his paper, Bielecki compared two EMP measures calculated under alternative methodologies (using all foreign reserve changes and pure official foreign exchange intervention data). He came to the conclusion that the appreciation pressure prevailed during the sample period. However, the behavior of the two indices differed to some extent, especially with events characterized by extreme EMP values (July 1997, August 1998,

[3] Some of the recent empirical studies examining EMP are Jeisman (2005) in Australia, Gohoco-Bautista and Bautista (2005) in Philippines, Bird and Mandrilas (2005) in Latin America, Carribean, Asian and Pacific regions, Wyplosz (2002) in a worldwide group of transition countries, Kamaly and Erbil (2000) in the MENA region or Kohlscheen (2000) in Chile.

February 1999 or July 2001). Generally, using the pure intervention data in the EMP estimation provided more realistic and robust results.

Vanneste et al. (2005) used EMP as an indicator of currency crisis and addressed the question whether currency crises in EU8 have been more frequent in fixed, intermediate or flexible exchange rate arrangements. The authors found that EMP was marginally smaller in countries and periods characterized by an intermediate exchange rate regime as compared to those with a floating arrangement. Regarding EU4, the most crisis quarters (excessive EMP) occurred in Hungary during the fixed peg regime and in Poland when a crawling peg was being applied. Managed floating proved to be a relatively stable regime from the EMP perspective. In addition to these conclusions, the authors also provided evidence of high correlation between several EMP measure specifications with which they experimented.

Very similar conclusions were drawn in Stavárek (2005) where EMP in the Czech Republic, Hungary, Poland and Slovenia in 1993-2004 is estimated. The study applied the EMP measure proposed in Eichengreen et al. (1995) and the results obtained suggest that the Czech Republic and Slovenia went through considerably less volatile development of EMP than Hungary and Poland.

Besides the focus on the still overlooked EU4 region, this paper contributes to the EMP literature in two basic aspects. First, it uses the most recent data and prolongs the period analyzed to the end of 2006. Second, this paper represents the very first concurrent application of the model-dependent and model-independent approaches on EU4 countries. Thus, the suitability of these models for EU4 countries can be evaluated.

3. Measuring the Exchange Market Pressure: Model and Data

3.1 Model-Dependent Approach

As mentioned previously, this study originally stems from Weymark (1995) where the following formula for EMP calculation was defined:

$$EMP_t = \Delta e_t + \eta \Delta r_t , \qquad (1)$$

where Δe_t is the percentage change in exchange rate expressed in direct quotation (domestic price for one unit of foreign currency), Δr_t is the change in foreign exchange reserves scaled by the one-period-lagged value of money base and η is the conversion factor which has to be estimated from a structural model of the economy and is defined as:

$$\eta = -\partial \Delta e_t / \partial \Delta r_t \ . \quad (2)$$

The conversion factor represents elasticity that converts observed reserve changes into equivalent exchange rate units.[4]

For practical estimation of EMP, the methodology introduced in Spolander (1999) was applied. Similarly with Weymark (1995), it is a model-consistent measure of EMP in the context of small open economy monetary model. However, the central bank's monetary and foreign exchange policies are explicitly defined, foreign exchange intervention partly sterilized, and expectations rational in the Spolander model. The model is summarized in equations (3) to (9):

$$\Delta m_t^d = \beta_0 + \Delta p_t + \beta_1 \Delta c_t - \beta_2 \Delta i_t \quad (3)$$

$$\Delta p_t = \alpha_0 + \alpha_1 \Delta p_t^* + \alpha_2 \Delta e_t \quad (4)$$

$$\Delta i = \Delta i_t^* + E_t(\Delta e_{t+1}) - \Delta e_t \quad (5)$$

$$\Delta m_t^s = \Delta d_t^a + (1-\lambda)\Delta r_t \quad (6)$$

$$\Delta r_t = -\overline{p}_t \Delta e_t \quad (7)$$

$$\Delta d_t^a = \gamma_0 + \Delta y_t^{trend} + (1-\gamma_1)\Delta p_t - \gamma_2 y_t^{gap} \quad (8)$$

$$\Delta m_t^d = \Delta m_t^s \quad (9)$$

where p_t is domestic price level, p_t^* is foreign price level, e_t denotes exchange rate (in direct quotation), m_t is nominal money stock (the superscript d represents the demand and s the supply), c_t is real domestic income, i_t is nominal domestic interest rate, i_t^* denotes nominal foreign interest rate, $E_t(\Delta e_{t+1})$ is expected exchange rate change and λ is proportion of sterilized intervention. All variables up to this point are expressed in natural logarithm. Next, d_t^a is autonomous domestic lending by the central bank and r_t is the stock of foreign exchange reserves, both divided by the one period lagged value of the money base. y_t^{trend} is the long-run trend component of real domestic output y_t and y_t^{gap} is the difference between y_t and y_t^{trend}. The sign Δ naturally denotes change in the respective variable.

Equation (3) describes changes in money demand as a positive function of domestic inflation and changes in real domestic income and a negative function of changes in the

[4] There is an assumption that all intervention takes the form of purchases or sales of foreign exchange reserves. When, in addition to this type of intervention, domestic credit changes are used to influence exchange rate, the EMP formula generated by log-linear models has the general form: $EMP_t = \Delta e_t + \eta[\Delta r_t + \lambda \Delta d_t]$ where λ is the proportion of the observed domestic credit change that is associated with indirect exchange market intervention.

domestic interest rate. Equation (4) defines the purchasing power parity condition attributing the primary role in domestic inflation determination to exchange rate changes and foreign inflation. Equation (5) describes uncovered interest rate parity. Equation (6) suggests that changes in the money supply are positively influenced by autonomous changes in domestic lending and unsterilized changes in the stock of foreign reserves. Equation (7) states that changes in foreign exchange reserves are a function of the exchange rate and a time-varying response coefficient $\overline{p}_t$. Equation (8) describes the evolution of the central bank's domestic lending. Whereas domestic inflation and changes in trend real output changes are positive determinants of the domestic lending the gap between real output and its trend has a negative impact on domestic lending activity. Equation (9) defines a money market clearing condition that assumes money demand to be continuously equal to money supply.

By substituting equations (4) and (5) into equation (3) and substituting equation (8) into equation (6) and then using the money market clearing condition in equation (9) to set the resulting two equations equal to one another, it is possible to obtain the following relation:

$$\Delta e_t = \frac{X_t + \beta_2 E(\Delta e_{t+1}) + (1-\lambda)\Delta r_t}{\gamma_1 \alpha_2 + \beta_2}, \tag{10}$$

where

$$X_t = \gamma_0 - \gamma_1 \alpha_0 - \beta_0 + \Delta y_t^{trend} - \gamma_1 \alpha_1 \Delta p_t^* - \gamma_2 y_t^{gap} - \beta_1 \Delta c_t + \beta_2 \Delta i_t^* \tag{11}$$

and the elasticity needed to calculate EMP in equation (1) can be found as:

$$\eta = -\frac{\partial \Delta e_t}{\partial \Delta r_t} = -\frac{(1-\lambda)}{\gamma_1 \alpha_2 + \beta_2}. \tag{12}$$

3.2 Model-Independent Approach

As mentioned above, Eichengreen et al. (1994, 1995) argued that dependency on a particular model was an undesirable feature for an EMP index. As an alternative, they proposed the following measure of speculative pressure:

$$EMP_t = \frac{\Delta e_t}{e_t} - \frac{1}{\sigma_r}\left(\frac{\Delta rm_t}{rm_t} - \frac{\Delta rm_t^*}{rm_t^*}\right) + \frac{1}{\sigma_i}(\Delta(i_t - i_t^*)) \tag{13}$$

where σ_r is the standard deviation of the difference between the relative changes in the ratio of foreign reserves and money (money base) in the analyzed country and the reference country $\left(\frac{\Delta rm_t}{rm_t} - \frac{\Delta rm_t^*}{rm_t^*}\right)$ and σ_i is the standard deviation of the nominal interest rate differential $(\Delta(i_t - i_t^*))$. Other variables are as defined in the previous specification.

However, for the practical calculation we took an inspiration from Sachs et al. (1996) and made some modifications of the EMP formula. We changed the weighting scheme to avoid the EMP measure being driven by the most volatile component and abandoned the relation between foreign reserves and money in home and reference country. Consequently, the EMP formula based on model-independent approach can be written as follows:

$$\begin{aligned} EMP_t = & \left(\frac{1/\sigma_e}{((1/\sigma_e) + (1/\sigma_{rm}) + (1/\sigma_i))}\right)\frac{\Delta e_t}{e_{t-1}} - \left(\frac{1/\sigma_{rm}}{((1/\sigma_e) + (1/\sigma_{rm}) + (1/\sigma_i))}\right)\frac{\Delta rm_t}{rm_{t-1}} + \\ & + \left(\frac{1/\sigma_i}{((1/\sigma_e) + (1/\sigma_{rm}) + (1/\sigma_i))}\right)(\Delta(i_t - i_t^*)) \end{aligned} \quad (14)$$

where σ_e is the standard deviation of the rate of change in the exchange rate $\frac{\Delta e_t}{e_{t-1}}$ and other variables are denoted consistently with (13).

3.3 Data

The samples of data used in this paper cover the period 1993:1 to 2006:4 yielding 56 quarterly observations for all EU4 countries. The data were predominantly extracted 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. Nevertheless, a brief overview of the data used is provided here for better understanding of the models described above.

We used nominal bilateral EU4 national currencies exchange rates against the euro (e_t). The exchange rates prior to 1999 were obtained using the irrevocable conversion rate of the German mark to the euro. The domestic (i_t) as well as foreign interest rate (i_t^*) are represented by the 3-month money market rates in EU4 countries and the Eurozone. The M1 monetary aggregate was employed as the domestic money stock (m_t). The domestic (p_t) and foreign price levels (p_t^*) are proxied by the respective consumer price index. As the level of domestic output (y_t) we applied the gross domestic product (GDP). The gross national income (c_t) was derived by adding the net income from abroad to GDP. The domestic money base (B_t)

and total reserves minus gold (r_t) were also included in the model-dependent EMP estimation. The proportional ratio of reserves (rm_t), used in the model-independent approach, was yielded by ratio of change in level of reserves and money base of previous period.

4. Estimation of the Exchange Market Pressure

4.1 Model-Dependent Approach

As is evident from the model presented in Section 3.1, the EMP estimation (1) must be preceded by the calculation of the conversion factor η (2, 12). This step is, however, required to obtain values of the sterilization coefficient λ (6), the elasticity of the money base with respect to the domestic price level γ_1 (8), the elasticity of the domestic price level with respect to the exchange rate α_2 (4), and the elasticity of the money demand with respect to the domestic interest rate β_2 (3).

More precisely, the parameter estimates are obtained by estimating the following three equations.

$$\Delta m_t - \Delta p_t = \beta_0 + \beta_1 \Delta c_t - \beta_2 \Delta i_t + \varepsilon_{1,t} \tag{15}$$

$$\Delta p_t = \alpha_0 + \alpha_1 \Delta p_t^* + \alpha_2 \Delta e_t + \varepsilon_{2,t} \tag{16}$$

$$\frac{\Delta B_t}{B_{t-1}} - \Delta r_t - \Delta y_t^{trend} - \Delta p_t = \gamma_0 + \lambda \Delta r_t + \gamma_1 \Delta p_t + \gamma_2 y_t^{gap} + \varepsilon_{3,t} \tag{17}$$

Equations (15) and (16) are obtained directly from equations (3) and (4). Equation (17) is derived by substitution of (7) into (5) and noting that change in money supply equals the change in money base $\frac{\Delta B_t}{B_{t-1}}$ assuming the money multiplier to be constant.

One can distinguish two types of variables included in the model: endogenous and exogenous. The endogenous variables are Δm_t , Δp_t , Δe_t , Δi_t , $\frac{\Delta B_t}{B_{t-1}}$ and Δr_t . The exogenous variables are Δc_t , Δp_t^*, Δi_t^*, Δy_t^{trend} and Δy_t^{gap} . Despite the fact that Δe_t does not appear on the left-hand side of any of the equations, it is the endogenous variable because the exchange rate is clearly the variable determined by this model.

The model is estimated using the two-stage least square regression technique (2SLS). The main reason is that the endogenous variables are on both sides of equations (3)-(9). It means that in each equation having endogenous variables on the right-hand side, these variables are likely to correlate with the disturbance term. Thus, using the ordinary least square method would lead to biased estimates. On the other hand, the three-stage least square method was not chosen because of the limited size of the dataset used (small number of observations).

The 2SLS used requires the incorporation of instruments (variables uncorrelated with the disturbance term) into the estimation. Thus, the first empirical step of the analysis was to find appropriate instruments. For this purpose we run the first stage regressions on endogenous variables having all possible instruments as regressors. As possible instruments we set the contemporaneous and one-quarter lagged values of exogenous variables and one-quarter lagged values of all endogenous variables. Finally, the regressors with sufficient statistical significance were selected as instruments. This procedure was carried out for all countries and equations of the model.

The next aspect which had to be assessed is the stationarity of regressors. This feature is essential for all regression models. We applied Phillips-Perron and Augmented Dickey-Fuller tests to examine the stationarity of the time series used. Uniform outcomes of both tests were necessary for the final conclusion about the (non)stationarity of each time series. According to the character of each time series we tested the stationarity with a linear trend and/or intercept or none of them. To conserve space the stationarity tests' results are not reported here but they allow us to conclude that the first differences of all time series are stationary. Thus, they can be used in estimation of all equations of the model.[5]

The 2SLS estimation results are presented in Tables 1 to 3, individually for each equation. The tables also contain the list of instruments and results of some diagnostic tests. We applied Jarque-Berra (J-B) indicator to assess normality of the residuals distribution, Breusch-Godfrey Langrange Multiplier (LM) to test serial correlation and White test to check heteroscedasticity. All LM tests were run with four lags. The tests indicated evidence of serial correlation in residuals from the equations and the potential heteroscedasticity was also identified in some cases. Therefore, we corrected the standard errors of parameter estimates by the Newey-West procedure. Even more frequently, the residuals seem to be non-normally distributed. Therefore although the t-statistics can be misleading, this does not reduce the

[5] The percentage change in money base is a naturally flow variable and, thus, already differenced and stationary. Likewise, y_t^{gap} is stationary on level in all countries because of its construction.

validity of the parameter estimates.[6] According to the model specification the parameters β_1, α_1, and α_2 should be positive and β_2, γ_1, γ_2, and λ should be negative. Since λ is a fraction, its absolute value should be between zero and one.

Table 1: Estimates of equation (15)

Czech Republic				Hungary			
instruments: Δy^{trend}_{t-1} Δr_{t-1} Δi_{t-1} Δy^{gap}_{t} Δp^{*}_{t-1}				instruments: Δc_{t} Δp^{*}_{t} Δi_{t-1} Δy^{trend}_{t-1}			
param.	estim.	st.er.	prob.	param.	estim.	st.er.	prob.
β_0	0.0019	0.0030	0.5350	β_0	-0.0047	0.0024	0.0508
β_1	0.0150	0.6767	0.9824	β_1	0.4307	0.2758	0.1246
β_2	-0.0401	0.0163	0.0175	β_2	-0.0490	0.0228	0.0364
R^2=0.0784, SEE=0.0094, DW=1.9026				R^2=0.1204, SEE=0.0102, DW=1.6233			
J-B=35.786 (0.0000), LM=6.1672 (0.1870) WHITE=24.917 (0.0001)				J-B=0.8773 (0.6448), LM=21.709 (0.0002) WHITE=10.894 (0.0278)			
Poland				Slovakia			
instruments: Δy^{trend}_{t-1} Δe_{t-1} Δi_{t-1} Δp^{*}_{t} Δc_{t-1}				instruments: Δc_{t-1} Δp^{*}_{t-1} Δm_{t} Δp_{t-1} Δi_{t-1}			
param.	estim.	st.er.	prob.	param.	estim.	st.er.	prob.
β_0	0.0014	0.0022	0.5292	β_0	0.0037	0.0038	0.3377
β_1	0.2229	0.1358	0.1068	β_1	-0.6755	0.6150	0.2772
β_2	-0.0891	0.0319	0.0073	β_2	-0.0624	0.0418	0.1417
R^2=-0.2486, SEE=0.0101, DW=2.3297				R^2=-0.7455, SEE=0.0165, DW=1.6467			
J-B=0.5631 (0.7546), LM=8.2077 (0.0842) WHITE=23.585 (0.0001)				J-B=71.840 (0.0000), LM=4.2942 (0.3676) WHITE=1.1746 (0.8823)			

Source: Author's calculations

The estimations of equation (15) provide mediocre results. The parameters β_2 necessary for the conversion factor calculation are correctly signed in all EU4. However, the parameter is not statistically significant in Slovakia. One can see some evidence of non-normal distribution (Czech Republic, Slovakia), serial correlation (Hungary) and heteroscedasticity (Czech Republic, Hungary and Poland).

In the estimations of equation (16) we obtained very good results. The signs of all parameters are consistent with the theoretical assumptions and important α_2 parameters are significantly different from zero in all countries. On the other hand, however, only error terms in the Polish and Slovak equations seem to pass the standard diagnostic tests completely. Furthermore, one can find a substantially lower elasticity of the domestic price level with respect to the exchange rate (α_2) in Poland and, to a lesser degree, in Slovakia than in other EU4. Although it is not directly linked with the EMP estimation, it is worthwhile to point out

[6] Since different equation specifications have different instruments, R^2 for 2SLS can be negative even if a constant is used in the equation.

a general feature of relatively high elasticity of the domestic price level with respect to the foreign inflation (α_1). One can find that quite common in small and open economies during the transition period.

Table 2: Estimates of equation (16)

Czech Republic				Hungary			
instruments: Δp_t^* Δy_{t-1}^{trend} Δi_{t-1}^* Δe_{t-1}				instruments: Δp_t^* Δy_{t-1}^{trend} Δc_t Δp_{t-1}			
param.	estim.	st.er.	prob.	param.	estim.	st.er.	prob.
α_0	0.0027	0.0014	0.0680	α_0	0.0012	0.0010	0.2593
α_1	0.9251	0.9693	0.3444	α_1	2.1007	0.9945	0.0396
α_2	0.8499	0.3573	0.0211	α_2	0.9970	0.1780	0.0000
R^2=-2.9594, SEE=0.0058, DW=1.7655				R^2=0.1440, SEE=0.0053, DW=1.7237			
J-B=10.022 (0.0066), LM=8.7911 (0.0665) WHITE=43.986 (0.0000)				J-B=0.0137 (0.9931), LM=10.021 (0.0401) WHITE=10.339 (0.0351)			
Poland				Slovakia			
instruments: Δp_t^* Δe_{t-1} Δi_{t-1} Δp_{t-1} Δc_{t-1} Δp_{t-1}^*				instruments: Δi_t^* Δe_{t-1} Δy_t^{gap} Δy_t^{trend} Δp_{t-1}^*			
param.	estim.	st.er.	prob.	param.	estim.	st.er.	prob.
α_0	0.0002	0.0021	0.9153	α_0	0.0035	0.0023	0.1351
α_1	2.8514	1.5569	0.0729	α_1	0.4775	1.8873	0.8013
α_2	0.2191	0.0383	0.0000	α_2	0.4904	0.2243	0.0334
R^2=-0.0007, SEE=0.0070, DW=1.7065				R^2=-0.6853, SEE=0.0048, DW=1.9955			
J-B=0.9986 (0.6070), LM=8.4745 (0.0756) WHITE=5.4510 (0.2441)				J-B=3.5220 (0.1719), LM=5.7802 (0.2162) WHITE=7.3479 (0.1186)			

Source: Author's calculations

The results from the money supply equation (17) are somewhat poorer. This is true because especially the estimation of the Polish equation led to confusing results. The parameter γ_1 has an opposite sign than the theory suggests and the absolute value of the sterilization coefficient λ exceeded the upper margin of the potential interval from zero to one. Moreover, γ_1 in all EU4 except for Hungary are statistically insignificant. Neither the performance of the elasticities of the money base with respect to the domestic output gap (γ_2) are significant (again, Hungary is the exception). According to Spolander (1999, p.72) this problem stems from different specification of the equation and, unfortunately, it is a common drawback of many studies of monetary policy rules and reaction functions. As stated in McCallum (1997, p.8), there has been much debate on the subject of monetary policy rules but the appropriate specification of a model suitable for the analysis of monetary policy rules does not exist.

Table 3: Estimates of equation (17)

Czech Republic				Hungary			
instruments: Δp_t^* Δy_t^{gap} Δr_{t-1} Δi_t^* Δi_{t-1} Δy_{t-1}^{trend}				instruments: Δy_t^{gap} Δi_{t-1}^* Δc_{t-1} Δy_{t-1}^{gap} Δi_{t-1}			
param.	estim.	st.er.	prob.	param.	estim.	st.er.	prob.
γ_0	-0.0035	0.0033	0.2980	γ_0	0.0017	0.0048	0.7150
λ	-0.6998	0.1821	0.0003	λ	-0.6971	0.1128	0.0000
γ_1	-0.5725	0.8973	0.5264	γ_1	-1.7175	0.7430	0.0250
γ_2	0.0003	0.0008	0.7334	γ_2	-0.0001	3.3E-05	0.0033
R^2=0.3475, SEE=0.0208, DW=2.0566				R^2=0.6565, SEE=0.0119, DW=2.5815			
J-B=822.14 (0.0000), LM=0.4953 (0.9739) WHITE=34.505 (0.0000)				J-B=38.062 (0.0000), LM=13.386 (0.0095) WHITE=3.7906 (0.7050)			
Poland				Slovakia			
instruments: Δm_{t-1} Δp_t^* Δy_{t-1}^{trend} Δp_{t-1}^* Δy_t^{gap}				instruments: Δy_{t-1}^{trend} Δc_t Δi_{t-1}^* Δy_{t-1}^{gap} Δi_{t-1}			
param.	estim.	st.er.	prob.	param.	estim.	st.er.	prob.
γ_0	-0.0039	0.0030	0.1916	γ_0	0.0083	0.0074	0.2693
λ	-1.4245	0.3236	0.0001	λ	-0.9005	0.1252	0.0000
γ_1	1.4541	1.1559	0.2143	γ_1	-3.1911	2.3325	0.1779
γ_2	-0.0003	0.0009	0.7247	γ_2	-0.0007	0.0021	0.7312
R^2=0.7436, SEE=0.0221, DW=2.4557				R^2=0.9512, SEE=0.0224, DW=2.4020			
J-B=14.541 (0.0007), LM=8.9796 (0.0616) WHITE=3.9895 (0.6780)				J-B=2.8966 (0.2349), LM=9.2211 (0.0558) WHITE=5.1728 (0.8189)			

Source: Author's calculations

The parameter estimates of the sterilization coefficients λ in all EU4 except for Hungary do not significantly differ from minus unity, which implies full sterilization.[7] However, the EU4 central banks have never publicly declared that all foreign exchange intervention has no impact on the money base. Hence, we assume that the parameter estimates of λ indicate less than full sterilization. This assumption is in accordance with the practice of central banks from developed countries which usually sterilize their intervention partially rather than fully.

Table 4 summarizes estimates of the conversion factors η calculated for all countries using equation (12). Due to non-standard results of the estimation of equation (17) in Poland, the Polish conversion factor differs substantially from other factors in magnitude as well as sign. The extraordinary value of Polish η is subsequently transmitted to EMP whose extent will not correspond with the EMP scale in other EU4.

[7] The Wald test of the null hypothesis λ=-1 resulted in the following F-statistics and probabilities. Czech Republic: 2.7181 (0.1055), Hungary: 7.2082 (0.0098), Poland: 1.7213 (0.1955), Slovakia: 0.5448 (0.4639).

Table 4: Estimates of conversion factors

Czech Republic	Hungary	Poland	Slovakia
3.227419	0.963507	-6.207188	1.167874

Source: Author's calculations

The EMP development according to model-dependent approach is graphically presented for all countries analyzed in Appendix 2. 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 figures contain, besides the EMP curve, the lines representing 1.5 multiple of the standard deviation above and below the mean EMP value. A breach of the corridor is considered as an excessive EMP, alerting to a potential crisis. Furthermore, the graphs are divided into several sections, thus allowing the distinguishing of different exchange rate arrangements applied in EU4 during the period examined.

One can find the EMP development in EU4 as alike in many aspects. The first three years were characterized by many episodes of excessive EMP and its high volatility. The EMP estimates suggest that there was a general pressure on EU4 currencies to depreciate. The principal exception was Poland whose EMP measurements surpassed 60% on the appreciation side in five quarters during 1993-1995. It is very hard to believe that the magnitude of money market disequilibrium would be so enormous that the Polish zloty (PLN) should have appreciated by 60% in order to remove that disequilibrium noting the still starting stage of the transformation process. Moreover, Vanneste et al. (2005) as well as Bielecki (2005) obtained considerably different (and more realistic) estimations of EMP in Poland in that period.

It is worthwhile to remember that all EU4 countries applied some version of fixed exchange rate regime in 1993-1995. Furthermore, the Czech Republic and Slovakia started their existence in January 1993 after the split of former Czechoslovakia. The related currency separation, launch of new currencies, establishment of new central banks, and formation of new monetary policies had an obvious impact on data used in the estimation and consequently on the EMP figures.

Since 1996, EMP developed more smoothly and free of any abnormal fluctuations. There was only one example of breaching the corridor's margin after 1995. In Hungary, EMP in 2002:1 was -1.96% suggesting a pressure on the forint (HUF) to appreciate. A high (not excessive) EMP also occurred at the end of 2002. HUF was under speculative attack on the upper edge of the band which culminated in devaluation of the central parity. In the Czech Republic, the highest EMP was identified in 2002:2 when the pressure reached 12.24% forcing the koruna (CZK) to depreciate. This reflected the necessity for a correction after the previous long-lasting appreciation and peaking at the historic high. Whereas the depreciation pressure prevailed on HUF and Slovak koruna (SKK) the proportion of appreciation-pressure and depreciation-pressure quarters was more balanced in the case of CZK in 1996-2006.

4.2 Model-Independent Approach

The EMP values obtained from the model-independent approach are substantially different from the model-dependent ones (see Appendix 3 for graphical illustration). They differ in magnitude as well as basic development tendencies. Since the comprehensive comparison of alternative results is provided in Section 4.3 we only focus here on description of the most notable features of the model-independent EMP.

None of the countries analyzed experienced extraordinary volatile development of EMP in the fist three or four years of the period examined. Far from it, the development in the Czech Republic and Poland at that period of time was the most stable ever. Furthermore, one can find many episodes of the excessive EMP in all countries during the second half of the period analyzed. Generally, the "crisis quarters" (EMP surpassing upper or lower limit) seem to occur more frequently in the model-independent than model-dependent approach. It is obvious as the "no-crisis band" in the model-independent approach is considerably tighter than the model-dependent band in three countries. However, all breaches of the limits are very temporary and, thus, the foreign exchange market disequilibrium did not last more than one observation (quarter). It is worth to mention a similarity in the very recent EMP development in three countries (Hungary, Poland and Slovakia). The pressure exceeded or came near the lower limit at the end of 2006 announcing the appreciation pressure on the national currencies.

Whereas the appreciation pressure prevailed during the entire period in the Czech Republic and Poland, the more balanced proportion of positive and negative EMP observations was revealed in Slovakia. Hungary, on the other side, had to face predominantly a depreciation pressure on HUF.

The most extreme EMP in the Czech Republic (+13.39%) can be observed in 2004:2. Such a high depreciation pressure was caused by increase of the Czech interest rate above the

Eurozone level and subsequent change in the interest rate differential (+210%). In Poland, we detected the most extreme EMP in 2005:4 (-20.56%). A separate analysis of the EMP components allows us to determine the principal cause. It is a substantial change in the reserves-money ratio (+12202.9%) driven by a massive increase in reserve holdings.

Slovakia is the country with the most numerous escapes from the no-crisis band, mainly on the appreciation side. However, the breaches of limits are rather marginal and the most significant one was recorded in 2005:1 (-7.75%) as a consequence of growing international reserves. Slovakia also witnessed a high depreciation pressure (+9.91%) in 1998:4, just after the shift in the exchange rate arrangement towards managed floating. In Hungary, we can distinguish, ignoring the very early stage, two cases of excessive depreciation EMP. The first one (+11.19%) occurred in 2003:3 following culmination of the speculative attack on appreciating HUF. In 2005:1, EMP reached even higher level (+13.78%) foreseeing the coming period of massive HUF depreciation.

4.3 Comparison of Alternative Approaches

As stated above, the alternative empirical approaches to the EMP estimation resulted in considerably different findings. It can be documented by descriptive statistics of the EMP time series as well as correlation analysis. The elementary descriptive statistics is presented in Table 5 and correlation coefficients of the EMP measures in Table 6.

Table 5: Descriptive statistics of exchange market pressure

	Czech Republic		Hungary		Poland		Slovakia	
	m_dep	m_ind	m_dep	m_ind	m_dep	m_ind	m_dep	m_ind
mean	0.0361	-0.0015	0.0091	0.0285	-0.1075	-0.0080	0.0352	0.0025
median	0.0036	-0.0011	0.0068	0.0228	-0.0362	0.0009	0.0062	0.0030
max	0.5544	0.1339	0.0578	0.1504	0.2150	0.1110	0.7466	0.0991
min	-0.0577	-0.1003	-0.0199	-0.0531	-0.6992	-0.2056	-0.0891	-0.0786
st. dev.	0.0948	0.0371	0.0165	0.0478	0.2005	0.0554	0.1170	0.0337
upper	0.1783	0.0488	0.0339	0.1002	0.1933	0.0751	0.2107	0.0532
lower	-0.1061	-0.0612	-0.0157	-0.0432	-0.4083	-0.0912	-0.1403	-0.0481

Source: Author's calculations

Notes: m_dep and m_ind denote model-dependent and model-independent approach respectively

The only country with results signaling some degree of consistency is Hungary. Means and medians of both EMP indices have positive signs and, furthermore, the correlation coefficient is the highest among all countries. One can find a further uniqueness in Hungarian results. Development of the model-dependent EMP was significantly less volatile than development of the alternative model-independent EMP. This is evident in standard deviation, width of the no-crisis band and spread between maximum and minimum values.

Totally opposite conclusions can be drawn on remaining countries. Their most notable common attributes are higher volatility of the model-dependent EMP and disharmonic development of the EMP measures mirrored in the reversely signed means and medians and low and/or negative correlation coefficients.[8] We should remind that the high standard deviations and wide bands stem from the varying development in the very early stage of the estimation period.

Table 6: Correlation coefficients of alternative exchange market pressure measures

Czech Republic	Hungary	Poland	Slovakia
0.086080	0.462380	-0.292988	0.192232

Source: Author's calculations

The consistency of the two EMP indices can also be assessed by discrepancies in identification of crisis. For that purpose, Figures 1-4 putting development of the both EMP measures together are presented. Moreover, Table 7 shows how many quarters were identified by the model-independent approach as crisis and how many of which would be similarly classified by the model-dependent approach if the model-independent no-crisis band applies. Table 7 also reports number of EMP crisis observations that were awarded with same sign and similar magnitude by both approaches. The results presented confirm the negligible consistency and provide evidence that the empirical tools used tend to interpret EMP development differently.

Table 7: Consistency of alternative approaches in identification of crises

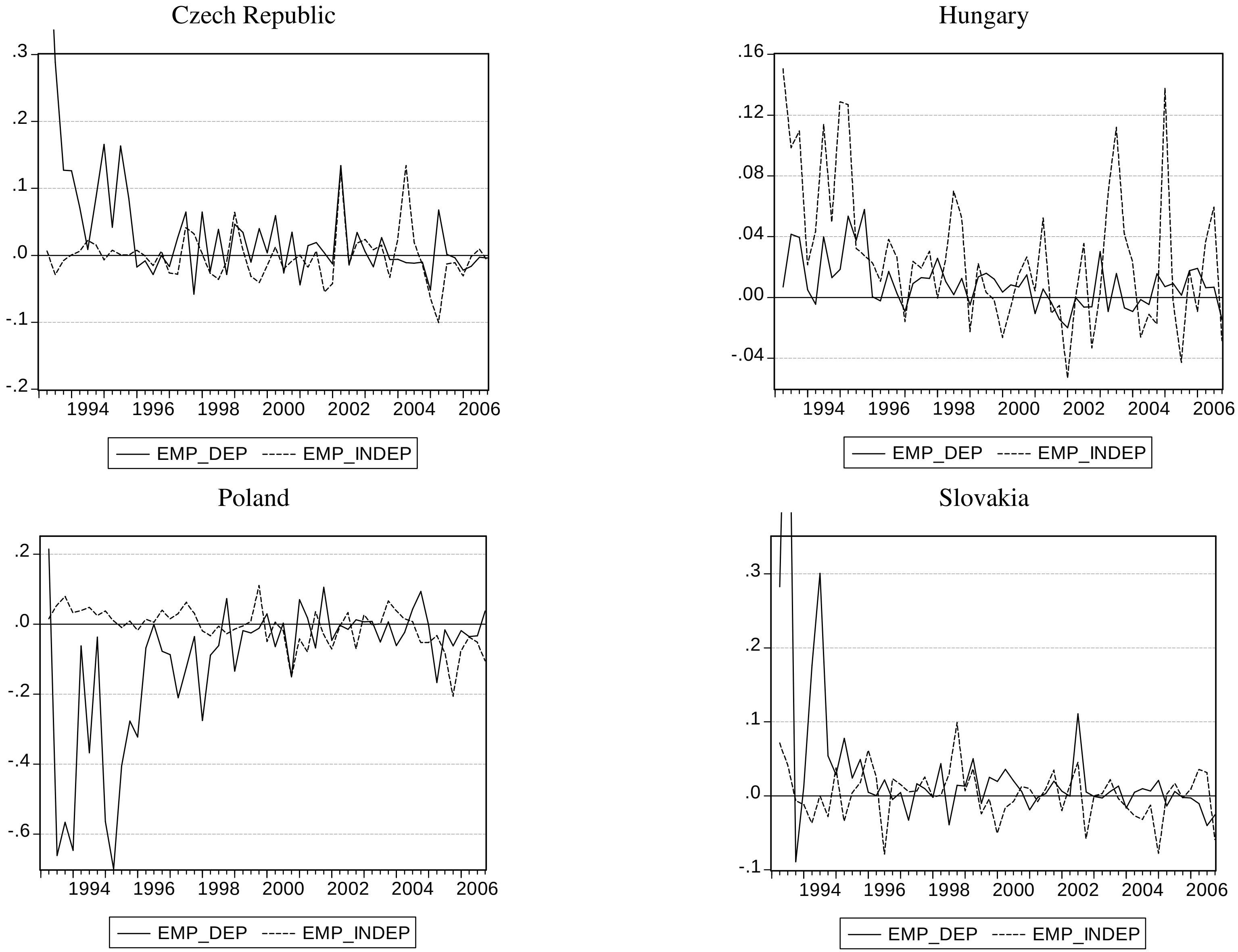
	Czech Republic	Hungary	Poland	Slovakia
m_ind crises	4	6	3	7
m_dep crises	1	0	1	0
same sign	2	6	2	3
similar magnitude	2	0	1	0

Source: Author's calculations

Notes: m_dep and m_ind denote model-dependent and model-independent approach respectively. Similar magnitude means that value of the m_dep EMP is within interval 50%-150% of the m_ind EMP value.

[8] We also carried out a cross-border correlation analysis that revealed generally higher correlation between model-dependent indices. The highest correlation coefficient can be observed between Czech and Slovak EMP (0.5456) and the most negative between Hungarian and Polish EMP (-0.6066). Correlation analysis of the model-independent EMP yielded to considerably lower coefficients. The highest one (0.2867) was calculated between Hungary and Poland.

Figures 1-4: Development of exchange market pressure based on model-dependent and model-independent approaches



Source: Author's calculations

One of the aims of the paper is to compare EMP in various exchange rate arrangements in EU4 keeping in mind the necessity to enter into ERM II (a quasi-fixed regime with a fluctuation band) and fulfill the exchange rate stability criterion in EU4 in the near future. The comparison of the EMP standard deviations calculated over the periods with particular exchange rate regime along with number of crisis quarters is provided in Table 8.

Table 8: Standard deviations of exchange market pressure and number of crisis quarters

	Czech Republic		Hungary		Poland		Slovakia	
	m_dep	m_ind	m_dep	m_ind	m_dep	m_ind	m_dep	m_ind
fixed (crawl) peg	0.1448 (0:0)	0.0148 (0:0)	0.0181 (2:0)	0.0458 (3:0)	0.3342 (0:2)	0.0212 (0:0)	0.1767 (2:0)	0.0336 (1:1)
crawling band	---	---	0.0165 (0:0)	0.0317 (0:0)	0.1291 (0:0)	0.0369 (1:0)	---	---
floating	0.0382 (0:0)	0.0438 (3:1)	0.0127 (0:1)	0.0483 (2:1)	0.0613 (0:0)	0.0605 (0:2)	0.0245 (0:0)	0.0339 (1:3)
ERM II	---	---	---	---	---	---	0.0164 (0:0)	0.0380 (0:1)

Source: Author's calculations

Note: The ratio in parentheses is (number of excessive depreciation EMP : number of excessive appreciation EMP)

The results clearly suggest that any conclusion about the relationship between EMP and exchange rate regime is extremely sensitive on selection of the EMP estimation method. Model-dependent and model-independent approaches lead to absolutely controversial findings on how EMP develop and fluctuate in particular exchange rate arrangement. The model-dependent approach provides evidence that EMP during the floating-regime period was very stable in all EU4 and the excessive deviations of EMP occurred sporadically. On the contrary, the periods of fixed arrangement witnessed numerous episodes of surpassing the 1.5 multiple of standard deviation level along with the more volatile development. The results of the model-independent approach are totally opposite. Generally, any kind of the fixed regime paved the way for both lower and less volatile EMP and fewer crisis periods.

To determine whether the differences among EMP values in various exchange rate regimes are statistically significant we carried out a single-factor Analysis of Variance (ANOVA). The EMP observations from all EU4 were gathered in the single dataset and grouped into four categories according to classification system applied in Table 8. The ANOVA test results for model-dependent as well as model-independent approach are reported in Table 9.

Table 9: ANOVA test results

	model-dependent approach			model-independent approach		
	no. observ.	mean	variance	no. observ.	mean	variance
fixed (crawl) peg	56	0.00236	0.06289	56	0.02115	0.00179
crawling band	44	-0.04109	0.01097	44	0.01596	0.00118
floating	115	0.00232	0.00161	115	-0.00610	0.00244
ERM II	5	-0.01622	0.00026	5	0.00292	0.00144
	F-statistics: 1.162374 P-value: 0.325034			F-statistics: 5.646847 P-value: 0.000963		

Source: Author's calculations

Note: Critical value of F-statistics is 2.646402.

The ANOVA tests show that the exchange rate regime does not influence the average of the model-dependent EMP considerably as the F-statistics is small and insignificant. On the other hand, the means of the grouped model-independent EMP are significantly different at 1% level. Thus, one can consider the floating arrangement as the environment contributing to the volatile development and excessive values of EMP.

The results obtained allow us to derive some policy implications. There is no empirical justification for the a priori concerns that a shift in the exchange rate regime from floating to the quasi-fixed ERM II would stimulate EMP to increase. More likely, the basic characteristics of the EMP development will be retained after the change. Thus, supposing that the recent level of EMP volatility and density of crisis observation revealed by the model-independent approach will remain unchanged, it would cast serious doubt on the European Commission's requirement that EU4 must participate in ERM II without substantial tensions on the exchange rates.

The doubt gains importance if the actual European authorities' position to the fulfillment of the exchange rate stability criterion is considered as decisive. When all relevant statements and declarations of the ECB, European Commission and Ecofin Council are summarized and combined with the approaches to the criterion assessments applied in the past, we can consider the use of the ERM II standard fluctuation band of ± 15% as highly improbable. On the contrary, the authorized fluctuation margin is likely to be asymmetric with the limits of 15% on the appreciation side and 2.25% on the depreciation side.

Although EMP fluctuated predominantly within this narrow band in EU4 in the last four years one can expect that all EU4 will have to face excessive EMP from time to time when participating in ERM II and fulfilling the exchange rate stability criterion. Since the depreciation part of the asymmetric band is very tight the EMP development should be monitored carefully. The depreciation EMP would principally require some policy actions taken by the central bank in the form of foreign exchange interventions or any other suitable instrument.

Owing to some factors the EMP estimates presented and discussed previously must be viewed with some degree of skepticism. There are several drawbacks of the model-dependent approach which must be taken into account when interpreting the results obtained. First, many parameter estimates required for calculation of the conversion factor and EMP are statistically insignificant. It can be attributed to either wrong specification of the model or some problems with estimation procedure or data used. Second, the parameter estimates are sensitive to the choice of instruments and even small changes in the parameters' values have a considerable impact on EMP. Third, the sterilization coefficient in all EU4 except for Hungary is not significantly different from minus unity which indicates full sterilization. Fourth, model-dependent EMP in all countries behaved almost absolutely parallel to changes in reserves during the entire period.[9] It implies a frequent application of the central bank official intervention even in the environment of floating exchange rate regime. The reality in many EU4 was, however, different. These limitations should be eliminated in future research. We recommend use of the pure foreign exchange intervention data as an alternative to the change in reserves. It could lead to more plausible results as evident in Bielecki (2005). The model could also be extended by the possibility of indirect intervention operating through changes in domestic lending or the domestic interest rate.

5. Conclusion

In this paper, we estimated EMP for the EU4 currencies against the euro exchange rate over the period from 1993-2005. We concurrently applied the Spolander (1999) model based on the Weymark (1995) model-dependent approach and model-independent approach based on Eichengreen et al. (1994, 1995) and Sachs et al. (1996). Fundamental differences in spirit and construction of these approaches are reflected in considerably different results. Thus, the principal conclusion of this study is a clear statement that the two empirical approaches applied are not compatible if data from EU4 are used. The two alternatives differ substantially

[9] This finding is based on results of a variance analysis of EMP and its components.

in assessment of the general development trends and tendencies as well as magnitude and direction of EMP in particular quarters.

According to model-dependent approach, EMP in the Czech Republic, Hungary and Slovakia is of similar magnitude. Whereas a depreciation pressure prevailed on HUF and SKK, no dominance of any direction of the pressure can be found in the case of CZK. The estimates of the Polish EMP are burdened by substantial statistical insignificance. The results obtained suggest that EMP in EU4 decreased over time and was substantially lower and less volatile during the periods of floating exchange rates than in the environment of fixed exchange rate regime. However, there are some concerns about the validity of the parameter estimates and consequently the EMP measures in all EU4. Therefore, we can conclude that the Spolander (1999) model in its pure version is not fully suitable for EU4 and we recommend some extensions and propose further steps for future research.

The model-independent approach is not burdened by the above mentioned drawbacks. Moreover, this approach puts greater emphasis on the interest rate differential, which has often been identified as a factor of exchange rate determination in EU4. Thus, results of the model-independent approach can be considered as more reliable. The EMP development can be described as homogeneous during the entire period analyzed without any stage of abnormal volatility or exceptionally frequent occurrence of excessive EMP. While CZK and PLN were largely under appreciation pressure, HUF was forced to depreciate and no dominance was revealed in Slovakia. However, the model-independent approach identified more crises than model-dependent approach including the very recent excessive pressure on appreciation of three EU4 national currencies.

The study did not confirm the concerns that the unavoidable shift in the exchange rate regime towards the quasi-fixed ERM II could evoke EMP to grow to excessive levels. Instead, the empirical tests suggest that the regime change will have, with high probability, a negligible impact on the EMP development. However, the asymmetric fluctuation band which is likely to be applied for the assessment of the fulfillment of the exchange rate stability criterion seems to be very tight on the depreciation side. Stemming from estimations obtained, the EU4 central banks will be probably confronted with occasions of excessive EMP jeopardizing fulfillment of the exchange rate stability criterion.

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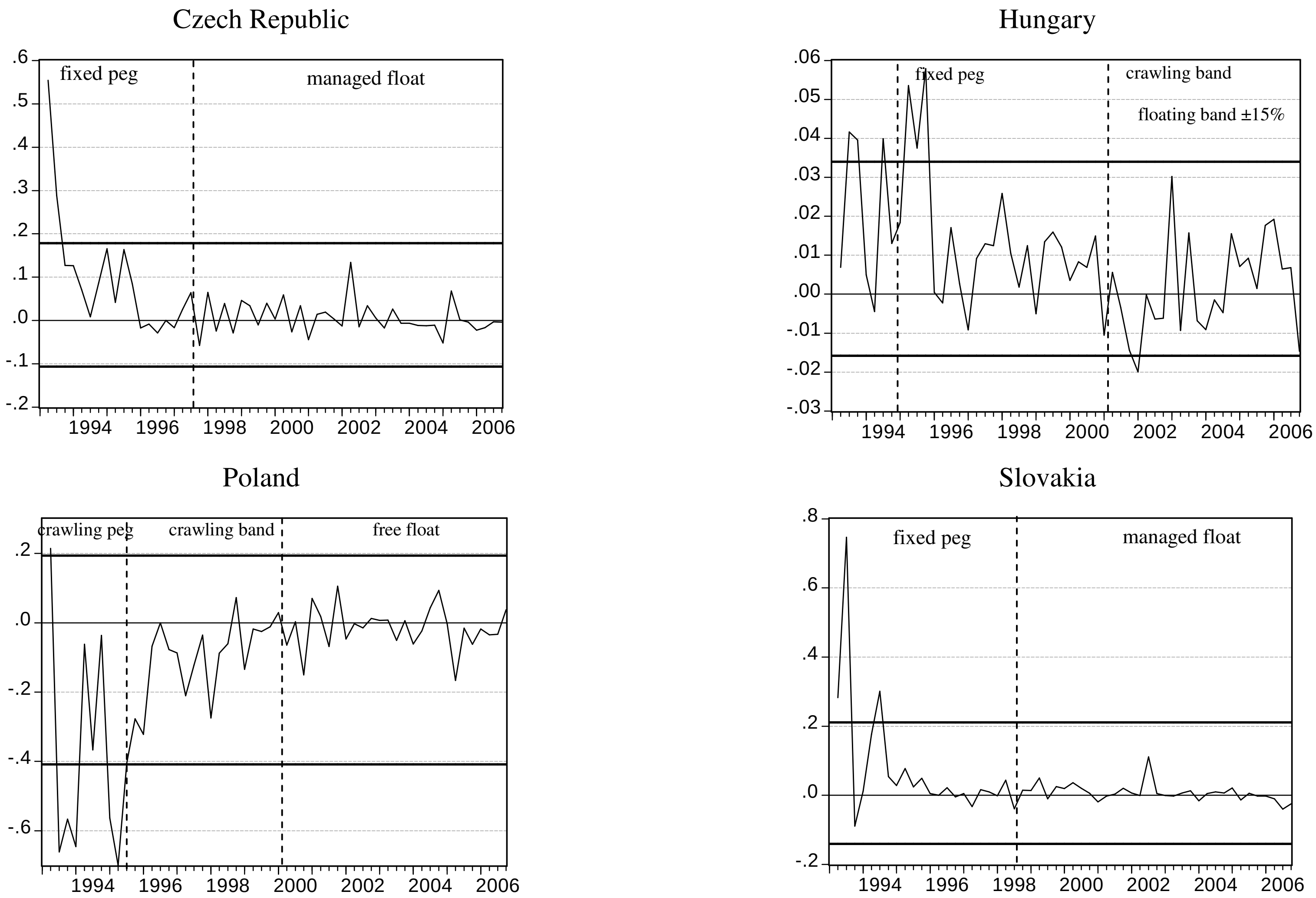
Appendix 1: Data description

All data are on quarterly basis and cover the period 1993:1 – 2005:4

B_t	EU4 national money base Obtained from IMF's International Financial Statistics (IFS) line 14 (Reserve money) and then logged.
c_t	EU4 Gross national income Derived by adding the net income from abroad to Gross domestic product (IFS line 99B). In national accounts statistics, the total of rents, interest, profits and dividends plus net current transfers is shown as "net income from abroad". It was obtained from IFS by differencing current account balance (IFS line 78ALD) and balance on goods and services (IFS line 78AFD). Logged values.
e_t	Nominal bilateral exchange rate of EU4 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.
i_t^*	Eurozone 3-month money market interest rate Obtained from EEF section Exchange rates and Interest rates, line Money market interest rates – Quarterly data, series MAT_M03
i_t	EU4 national 3-month money market interest rate Obtained from EEF section Exchange rates and Interest rates, line Money market interest rates – Quarterly data, series MAT_M03
m_t	EU4 national M1 monetary aggregate Obtained from IFS line 34..B (Money, Seasonally Adjusted) and then logged.
p_t^*	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.
p_t	EU4 national 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.
r_t	EU4 national official reserves holdings Obtained from IFS line 1L.D (Total Reserves Minus Gold) converted to national currency using nominal bilateral exchange rate vis-à-vis US dollar (IFS line AE) and then logged.
rm_t	Proportional change in domestic international reserves Obtained by ratio of change in the level of reserves (IFS line 79DAD) and money base of previous period (IFS line 14).
y_t	EU4 national Gross domestic product Obtained from IFS line 99B (Gross Domestic Product) and then logged.
y_t^{trend}	Long-run component of y_t Obtained using the Hodrick-Prescott filter and a smoothing parameter of 1600, as recommended for quarterly data.

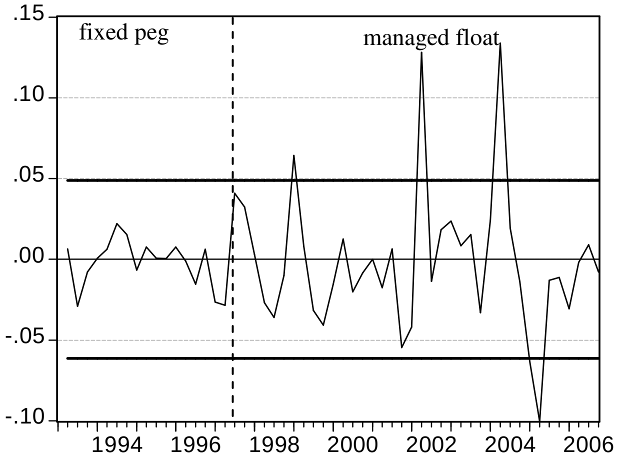
Appendix 2: Exchange market pressure in EU4 countries (model-dependent approach)



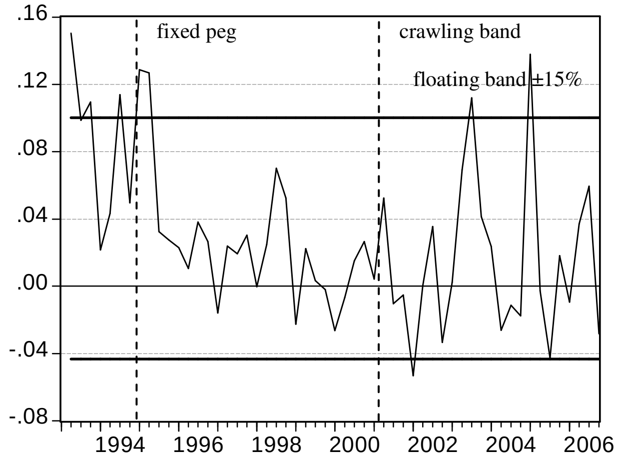
Source: Author's calculations

Appendix 3: Exchange market pressure in EU4 countries (model-independent approach)

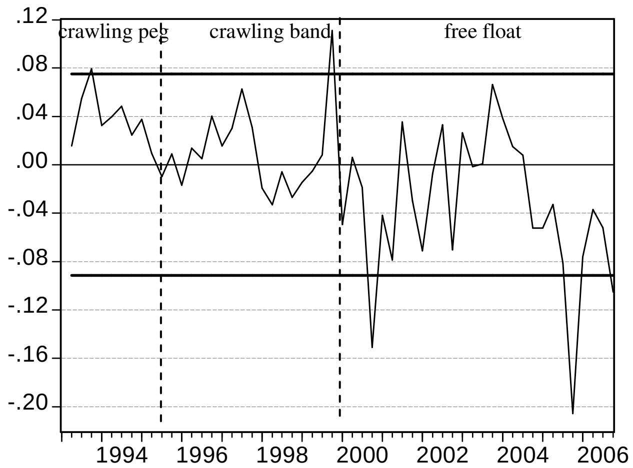
Czech Republic



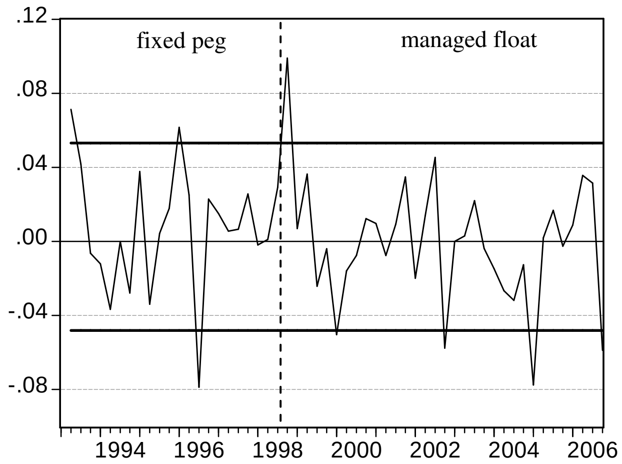
Hungary



Poland



Slovakia



Source: Author's calculations