ELSEVIER

Economic Systems 32 (2008) 103–118

ECONOMIC SYSTEMS

www.elsevier.com/locate/ecosys

Volatility of exchange rates in selected new EU members: Evidence from daily data

Jarko Fidrmuc [a,b,c,*], Roman Horváth [d]

[a] *Department of Economics, University of Munich, Germany*
[b] *CESifo, Germany*
[c] *Comenius University Bratislava, Faculty of Mathematics, Physics and Informatics, Slovakia*
[d] *Czech National Bank; and Institute of Economic Studies, Charles University, Czech Republic*

Received 27 November 2006; received in revised form 15 July 2007; accepted 3 September 2007

Abstract

We examine the daily exchange rate dynamics in selected new EU member states (Czech Republic, Hungary, Poland, Romania, and Slovakia) using GARCH and TARCH models between 1999 and 2006. Despite these countries' adopted inflation targeting regime, they occasionally tried to manage their exchange rates. We find that the low credibility of exchange rate management implied higher volatility of exchange rates when it substantially deviated from the implicit target rates for all countries. Finally, we find significant asymmetric effects of the volatility of exchange rates in all analyzed countries.

JEL classification: F31; C22; C23

Keywords: Exchange rates; Target zones; ERM II; Inflation targeting; GARCH

1. Introduction

All new member states (NMS) of the EU face a trade-off between exchange rate stability and flexibility. The recent literature on optimum currency area (OCA) criteria in the NMS surveyed by Fidrmuc and Korhonen (2006) shows that these countries increasingly constitute an optimum currency area with the EMU. Similarly, Horváth (2007) finds that the NMS fulfill OCA criteria at

* Corresponding author at: Department of Economics, University of Munich, Germany.
E-mail addresses: jarko.fidrmuc@lrz.uni-muenchen.de, jarko.fidrmuc@fmph.uniba.sk (J. Fidrmuc).

0939-3625/$ – see front matter
doi:10.1016/j.ecosys.2007.09.004

approximately the same level as the euro area countries before they adopted the euro, suggesting that the benefits of exchange rate stability may prevail.

By contrast, the developments especially in Central Europe[1] showed a process of increasing exchange rate flexibility during the previous decade (see Markiewicz, 2006, and Frömmel and Schobert, 2006). This development has been reversed only recently by the first accessions to the Exchange Rate Mechanism II (ERM II) and the starting process of euro adoption in the NMS of the EU.[2] In the specific conditions of these countries, relatively flexible exchange rate regimes have appeared to be appropriate to deal with the high capital flows, productivity improvements and the appreciation of exchange rates also in nominal terms (see Égert and Lommatzsch, 2004). At the same time, the exchange rate peg was replaced by monetary policies, putting more emphasis on inflation stabilization (see Kočenda et al., 2006). Actually, nearly all countries of our sample have adopted different types of inflation targeting.[3] Still, several NMS have used interventions at the foreign exchange market (see Égert, 2007; Égert and Komárek, 2006; or Geršl and Holub, 2006). On the one hand, these actions were largely motivated by inflation and competitiveness pressures, which in small and open economies heavily depend on exchange rates. On the other hand, this development corresponds also to the fear of floating phenomenon analyzed by Calvo and Reinhart (2002).

These arguments mean that some NMS are likely to pursue a de facto exchange rate policy of implicit target zones around time-varying target exchange rates,[4] which is similar to the proposal of target zone around a fundamental equilibrium exchange rate proposed by Williamson (1985), Edison et al. (1987), and Chmelarova and Schnabl (2006). Similarly, like in Krugman's (1991) exchange rate target zone model, the volatility of exchange rate at the borders of target zones should be smaller than in the area close to the central parity if the regime is fully credible. In the opposite case, we should observe that exchange rate volatility increases with the distance from the target exchange rates. The opposite case is especially appealing for us, as we model the countries that did not adopt official target zones, but rather tried to keep the exchange rates relatively stable.

Furthermore, expectations may in principle be formed differently in the appreciation and depreciation parts of the target zones (either de jure or de facto), which may cause systematic asymmetric effects. This pattern of exchange rate behavior can be estimated by generalized autoregressive conditional heteroskedasticity (GARCH) models. Potential asymmetry in exchange rate volatility is addressed by threshold autoregressive conditional heteroskedasticity (TARCH) models (see Kočenda, 1998).

The paper is structured as follows. The next section reviews the literature on the exchange rate target zones. Section 3 presents data and Section 4 estimates GARCH models. Finally, Section 5 concludes. Additional sensitivity results are presented in Appendix A.

[1] On the other hand, several smaller transition economies in South East Europe and in the Baltics have adopted currency boards or comparably fixed exchange rate regimes. This development confirms Eichengreen's (1994) bipolar hypothesis that small and open economies have to decide between the extreme points of exchange rate flexibility.

[2] Estonia, Lithuania and Slovenia joined the ERM II in 2004, while Cyprus, Malta, Latvia and Slovakia followed in 2005. Furthermore, Slovenia introduced the euro by January 2007, and Cyprus and Malta in January 2008.

[3] Czech Republic and Poland adopted inflation targeting in 1998, Romania and Slovakia followed after a period of informal inflation targeting in 2005. Hungary adopted inflation targeting regime in mid-2001 and accompanied it with a managed exchange rate with the fluctuation band of $\pm 15\%$.

[4] For example, the National Bank of Slovakia declared its official conduct of the monetary policy as "inflation targeting in the conditions of the ERM II" in 2004 (see NBS, 2004). Nell (2004, p. 24) states that "implicit inflation targeting . . . is not in conflict with the exchange rate arrangement and has thus far served the NBS rather well".

2. Related literature

A fixed exchange rate regime with a non-zero fluctuation band is generally referred to as a target zone (see for example Ghosh et al., 2003). The motivation for maintaining a target zone exchange rate regime is typically that some flexibility in exchange rate fluctuations is allowed, while the bands in principle assure an elimination of the eventually excessive fluctuations common under free float exchange rate regime. For a comprehensive survey of this literature, we refer the reader to Kempa and Nelles (1999), Obstfeld and Rogoff (1998), and Sarno and Taylor (2002). Bessec (2003) and Chung and Tauchen (2001) review models with asymmetric and implicit target zones.

Krugman (1991) provides a seminal contribution to an analysis of exchange rate dynamics under target zones. The early naive approach to exchange rate modeling in the target zone assumed that the exchange rate behaves as the free float inside the band and as the fixed exchange rate regime at the edge of the band. In consequence, the fluctuation band has no influence on exchange rate behavior inside the band. However, Krugman (1991) stresses the role of exchange rate expectations and argues that the existence of a credible fluctuation band influences the exchange rate behavior not only at the edge of the band, but also inside the band. Consequently, when the exchange rate is close to the edge of the band, the foreign exchange market participants expect interventions to keep the exchange rate inside the band. As a result, the expected change of the exchange rate is non-zero. It is positive if the exchange rate reaches the weaker side of the fluctuation band, and vice versa. Thus, exchange rate is mean-reverting (this is typically labeled as honeymoon effects in the target zone literature). Besides, the exchange rate becomes completely insensitive to fundamentals at the edges of the band (which is referred to as smooth pasting).

There have been several papers examining the Krugman model empirically. Engle and Gau (1997) examine whether the position of spot exchange rate within the band is associated to its volatility using the data from several EU countries participating in the European Monetary System between 1986 and 1993. They find rather mixed support for the Krugman model, namely only in a few countries the negative relationship between the deviation of the exchange rate from its central parity and the exchange rate volatility is detected. Crespo-Cuaresma et al. (2005a) study exchange rate dynamics in a majority of EU members over different sample periods. Primarily, they test for the so-called effective band within the officially announced band. The motivation is that central banks typically do not wait until the exchange rate hits the official band, but rather start intervening already within the band. Chmelarova and Schnabl (2006) discuss the intervention pattern based on Krugman's model in Croatia as compared to developed countries.

Exchange rate volatility in selected NMS is also analyzed by Kočenda and Valachy (2006) and Schnabl (2008). They find that exchange rate volatility generally increased with the introduction of more flexible exchange rate arrangements. Furthermore, the level of interest rates differential decreases exchange rate volatility, while the volatility of interest rates differential has the opposite effect.

3. Data description

Our dataset contains the daily euro exchange rates in the Czech Republic, Poland, Romania, Hungary, and Slovakia between January 1997 and May 2007. However, we restrict our data sample to the period starting in January 1999. On the one hand, the starting point of our analysis is determined by the creation of the euro. Thus, we avoid observations characterized by possibly

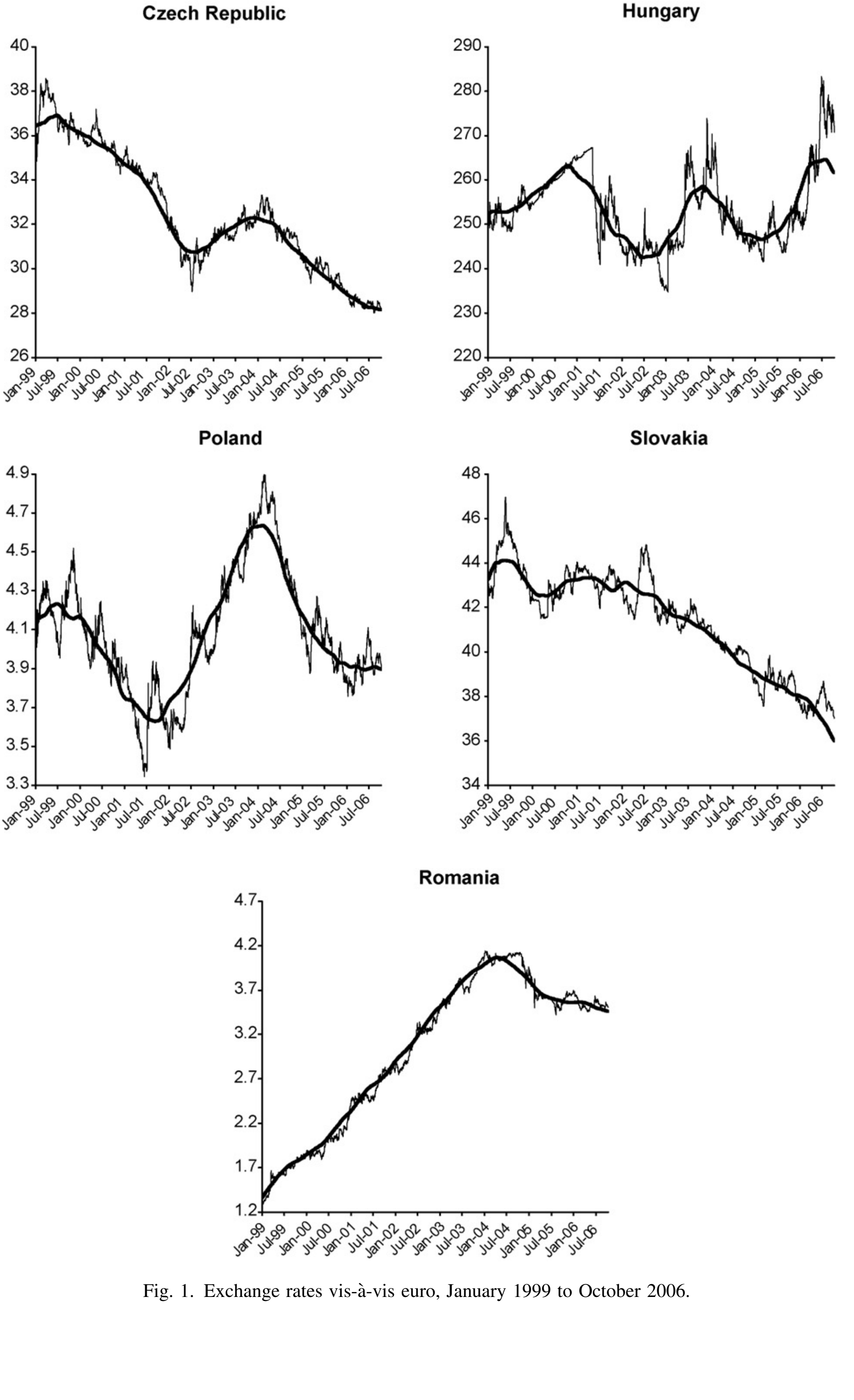

Fig. 1. Exchange rates vis-à-vis euro, January 1999 to October 2006.

non-standard volatility due to the change-over in the euro area countries. On the other hand, all NMS introduced inflation targeting regimes in this period with less emphasis on exchange rate stabilization. These countries also did not experience any currency crisis during the analyzed time. We exclude all countries with currency boards (Bulgaria and the Baltic States) and Slovenia, which introduced the euro in 2007, from our analysis.

As a result, our analysis concentrates on the daily exchange rates of the euro in the Czech Republic, Hungary, Poland, Slovakia, and Romania between January 1997 and May 2007. The implicit target exchange rate is approximated by 240th moving average mode (that is, the average of ±120 trading days or approximately one year).[5] The computation of moving average restricts our estimation period from January 1999 to October 2006, which provides about 2000 observations.[6]

The selected new member states of the EU used highly heterogeneous de facto and de jure exchange rate policies. All countries in our sample allowed officially for free exchange rate movement to a significant degree. However, only Poland has been widely acknowledged not to intervene in the foreign exchange market (see Frömmel and Schobert, 2006). In turn, the Czech Republic and Slovakia allowed for considerable but controlled fluctuations of their currencies. Similarly, Hungary followed a policy of broad fluctuation bands (since 2001), while Romania had a de facto crawling peg until 2005.

These institutional differences also cause different developments of nominal exchange rates against the euro. Fig. 1 presents the exchange rate developments for our sample countries. Generally, nominal exchange rate appreciation is visible for the Czech Republic and Slovakia. On the other hand, the Polish exchange rate does not seem to exhibit any pattern during the analyzed period. Finally, the Romanian leu depreciates substantially until 2004, which corresponds to the de facto crawling peg applied by the Bank of Romania. Furthermore, we can see in all selected NMS that the periods of high exchange rate volatility are usually associated with fast movements either in the appreciation or depreciation directions.

Table 1 provides the descriptive statistics between January 1999 and October 2006. Using the coefficient of variation (standard deviation divided by mean of individual currencies), Hungarian and Slovak currencies are characterized by the most stable exchange rates, followed by the Polish zloty and the Czech koruna. However, there were different sources of volatility between the countries. Depreciation dominated only in Romania until 2004, while appreciation trends played an important role in the Czech Republic, Slovakia, and Romania (since 2005). The volatility in Hungary and Poland is mainly due to frequent changes of depreciation and appreciation developments.

4. Results

4.1. GARCH models

The GARCH models are generally applied for the estimations of the conditional volatility of high-frequency (daily) exchange rate changes (see Baillie and Bollerslev, 1989). Following Engle and Gau (1997), we test one of the implications of the Krugman (1991) model of target

[5] Moving average, as the approximation of equilibrium exchange rate, is also adopted e.g. by Ito and Yabu (2007) and Chmelarova and Schnabl (2006).

[6] Alternatively, we use the time variable trend proxied by the Hodrick–Prescott filter (available upon request from authors).

Table 1
Descriptive statistics for daily exchange rates, January 1999 to October 2006

	Czech Republic	Hungary	Poland	Slovakia	Romania
Mean	32.525	253.596	4.083	41.404	3.028
Median	31.883	252.555	4.055	41.772	3.365
Maximum	38.583	283.350	4.935	46.977	4.143
Minimum	28.000	234.720	3.343	36.840	1.287
Standard deviation	2.730	8.808	0.314	2.226	0.840
Coefficient of variation (%)	8.393	3.473	7.684	5.376	27.727
Skewness	0.276	0.585	0.301	-0.268	-0.476
Kurtosis	2.005	3.112	2.826	2.107	1.832
Jarque–Bera test	109.403 [0.000]	116.877 [0.000]	33.107 [0.000]	91.721 [0.000]	191.726 [0.000]
Observations	2028	2028	2028	2028	2028

Notes: p-values are reported in the brackets.

zones. Krugman shows that the conditional volatility of the exchange rate decreases as the exchange rate approaches the edge of the target band. As a result, we estimate whether the deviation of the exchange rate from its target rate decreases the conditional volatility. Our baseline specification is a GARCH (1,1) model,

$$\Delta s_{jt}^{D} = \mu_j + \xi_{jt}, \tag{1}$$

$$\sigma_{jt}^2 = \gamma_{j1} + \gamma_{j2}\xi_{jt-1}^2 + \gamma_{j3}\sigma_{jt-1}^2 + \delta_j|s_{jt-1}^D - s_{jt-1}^F| + \omega_{jt} \tag{2}$$

where s^D and s^F denote the spot daily exchange rate of currency to euro and the time-varying target rate (moving average of $\pm$120 trading days), respectively. We do not include any explanatory variables except for constant to Eq. (1), because daily exchange rates are expected to be influenced largely by news and other random events (see Bask and Fidrmuc, 2006, for the discussion of high-frequency exchange rate movements in the NMS). The constant term in Eq. (1), μ, shows the average rate of appreciation or depreciation. The error term, ξ, of the mean Eq. (1) is assumed to have a time-varying conditional variance, σ^2, specified by Eq. (2).

The conditional variance equation includes in addition to the ARCH term, ξ_{t-1}^2, the GARCH term, δ_{t-1}^2, and the distance between the spot and the target exchange rates, which is the major variable of our interest. Krugman's (1991) model implies that δ is negative, i.e. the conditional volatility decreases as the exchange rate moves towards the edge of the band, as long as the announced or implicit target zones are fully credible. The opposite is true for the target zones subject to speculative attacks and low credibility. Finally, we expect no relationship between the conditional variance and the target exchange rates if no implicit target zones are specified.

Table 2 reports the estimations of (1) and (2) for the Czech Republic, Hungary, Poland, Slovakia, and Romania between January 1, 1999, and October 11, 2006.[7] The results provide several interesting insights. First, the appreciation trend is confirmed for the Czech Republic, Poland and Slovakia. Our estimates at daily frequency imply an annual appreciation by 3–5%. In turn, the Romanian leu and to a lesser degree the Hungarian forint depreciated significantly

[7] We report GARCH (1,1) for the ease of exposition as we find that this specification has the lowest Schwarz information criterion for almost all countries.

Table 2
Estimates of the effect of the spot position to the target value on conditional volatility (GARCH models), January 1999 to October 2006

Country	Czech Republic	Hungary	Poland	Slovakia	Romania
μ	-0.013^{*} (-1.944)	0.005 (1.019)	-0.020 (-1.558)	-0.011^{*} (-1.681)	0.024^{**} (2.482)
γ_1	0.000^{***} (5.284)	0.000^{***} (-13.788)	0.000^{***} (3.307)	0.000^{***} (5.291)	0.000 (0.291)
γ_2	0.075^{***} (11.254)	0.111^{***} (20.482)	0.081^{***} (9.070)	0.093^{***} (10.527)	0.114^{***} (16.524)
γ_3	0.876^{***} (67.241)	0.881^{***} (179.706)	0.877^{***} (78.776)	0.852^{***} (62.728)	0.878^{***} (147.083)
δ	1.510^{***} (3.472)	3.670^{***} (24.097)	3.340^{***} (6.124)	1.430^{***} (5.988)	2.580^{***} (7.472)
$\gamma_2 + \gamma_3 = 1$	0.951^{***} [0.000]	0.992^{***} [0.005]	0.958^{***} [0.000]	0.944^{***} [0.000]	0.992^{*} [0.052]
SIC	-8.610	-8.543	-7.388	-9.082	-7.630
N	20028	20028	20028	20028	20028
L-B(10), RES	5.372 [0.865]	12.445 [0.256]	19.199 [0.038]	12.247 [0.200]	13.708 [0.187]
L-B(10), SQRES	5.262 [0.873]	1.565 [0.999]	15.802 [0.105]	4.587 [0.869]	8.266 [0.603]

Notes: we report z-statistics in parentheses and p-values of the Wald test that $\gamma_2 + \gamma_3 = 1$ and the Ljung–Box Q-statistics of the 10th lag for standard and squared residuals in brackets. For clarity of the discussion in the text, the coefficients μ and δ are multiplied by 100 and 10^4, respectively.

* Denote significance at 10%.

** Denote significance at 5%.

*** Denote significance at 1%.

during the period. The former development corresponds to the de facto crawling peg applied by the Bank of Romania (see Crespo-Cuaresma et al., 2005b).

Second, we can see that the conditional volatility significantly depends on actual lagged squared error term and lagged conditional variance of the error term. Furthermore, the sum of the ARCH and GARCH term is relatively high, which indicates that the volatility of the shocks in all countries is quite persistent. Nevertheless, the sum of both coefficients is significantly lower than unity in all countries except for Romania.

Finally, we find that the deviation of the spot exchange rate from its target level is positive and highly significant for all the countries. This implies that as the target bands were implicit, they generally suffered under their low credibility. Similarly to, e.g., Borghijs and Kuijs (2004), our results suggest that exchange rates do not act as shock absorbers. Our estimations show that exchange rate deviations from the medium-run average are characterized by significantly higher volatility. Thus, exchange rates may be a source of macroeconomic destabilization if they approach the ranges of the implicit target zones. The economic actors have to deal both with high deviations of exchange rates from their previous levels and their increased volatility. Nevertheless, we have to keep in mind that all coefficients are very small, although Hungary and Poland show the highest impact (in absolute value) of exchange rate deviations from the exchange rate target. In case of Slovakia, we have to include MA(1) in the mean equation to assure white noise in the residuals.

As a robustness check, we estimated the GARCH models with Hodrick–Prescott filter as an alternative to the moving average time-varying target rate, s^F. The results are largely unchanged.[8] Finally, we also estimated the GARCH models for the most recent sub-period after the countries (with the exception of Romania) joined the EU (that is, May 2004 to October 2006). We confirmed the positive coefficient for the distance of spot exchange rate from its implicit target value for all countries with the exception of the Czech Republic, while the coefficient for Poland is no longer significant (but positive) in this sub-sample (see Appendix A).

Fig. 2 presents the conditional variance for all countries in our sample. The Czech Republic and Slovakia show a lower conditional variance than other countries of the region in selected periods. Nevertheless, we can see frequent changes of the conditional variance in all NMS.

4.2. TARCH models

We can often see that the volatility of financial variables is different along positive and negative trends (see Engle and Ng, 1993). The downwards movements of share prices are usually associated with higher volatility of financial data. In this regard, Zakoïan (1990) and Glosten et al. (1993) proposed the threshold ARCH models to analyze asymmetric volatility.

Economic policy may also be likely to fight against the currency depreciation more intensively than against the appreciation. One reason for this asymmetry can be the fact that countries in this region typically experience real exchange rate appreciation partially due to the Balassa–Samuelson effect (Égert and Lommatzsch, 2004; García-Solanes et al., 2008, and MacDonald and Wójcik, 2008). Additionally, the ERM II even has some certain inherited

[8] We have also included the distance between the spot and implicit target rate in the mean equation. Except Romania, the coefficient was never significant at any obvious significance level. In the case of Romania, we find the positive impact of distance on the changes of exchange rate, which likely corresponds to the exchange rate policy of crawling band. These results are available upon request.

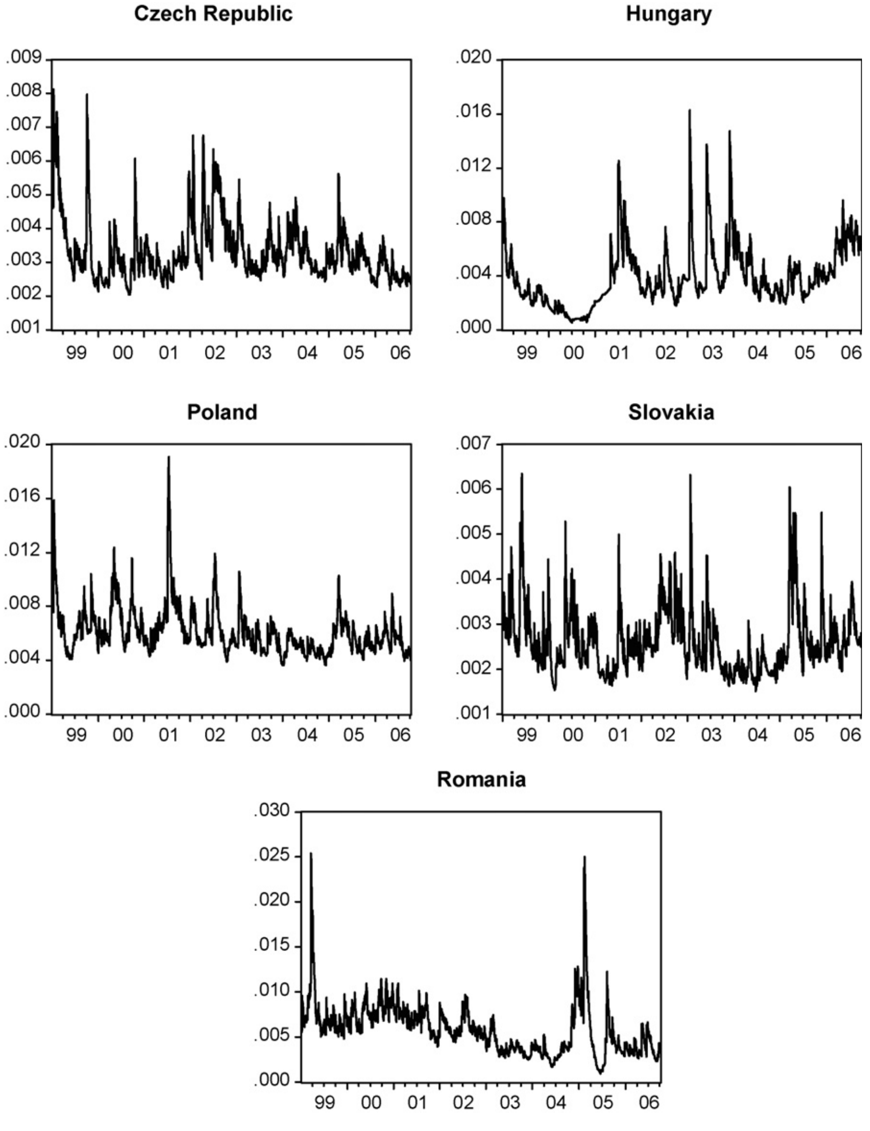

Fig. 2. Conditional standard deviation, January 1999 to October 2006.

asymmetric components as countries are allowed to appreciate the central parity, but its depreciation causes a violation of the exchange rate criterion (see De Grauwe and Schnabl, 2005).[9] This pattern of behavior may play an important role already during the preparation for the membership in the ERM II. Thus, the exchange rate target zones may be more credible if the exchange rate is approaching the depreciation limit (that is, the upper bound according to our definition of exchange rates) of the implicit target band.

[9] In March 2007, Slovakia appreciated the central parity by more than 8%.

In turn, national economic policies may define their objectives in relation to the national competitiveness. Several transition countries have often been concerned by the excessive exchange rate appreciation and some even aimed to stabilize its real exchange rate (see Coricelli et al., 2006). This may be especially important for the NMS with the strong appreciation trends due to the Balassa–Samuelson effect, deregulation of prices and tradable prices appreciation. Finally, market participants may behave differently if exchange rate is overvalued or undervalued. Actually, Crespo-Cuaresma et al. (2005a) find important asymmetric volatility effects both in EU15 countries as well as in the NMS.

Correspondingly, we extend the standard TARCH model as we also take into account the position of the spot exchange rate in relation to its target value. Our estimation specification is as follows:

$$\Delta s_{jt}^{D} = \mu_j + \xi_{jt}, \tag{3}$$

$$\sigma_{jt}^2 = \gamma_{j1} + \gamma_{j2}\xi_{jt-1}^2 + \gamma_{j3}\sigma_{jt-1}^2 + \gamma_{j4}D_{jt-1}^{\text{arch}}\xi_{jt-1}^2 + \delta_{j1}|s_{jt-1}^D - s_{jt-1}^F| + \delta_{j2}D_{jt-1}^{s}|s_{jt-1}^D - s_{jt-1}^F| + \omega_{jt}, \tag{4}$$

where D^{arch} is a dummy variable which equals 1 if the residual from the mean equation, ξ_t, is negative and zero otherwise. Similarly, D^s is a dummy variable equal to 1 if the spot exchange rate is lower than the target value, that is, if the exchange rate is in the appreciation part of the target zone.

The asymmetric ARCH terms, γ_4, is insignificant only in the Czech Republic and Slovakia, while the coefficient is negative in Poland and Hungary, and positive in Romania. As a result, negative (squared) residuals from the mean equation lower significantly to the exchange rate volatility in Hungary and Poland. Because the residuals are computed only from the mean equation, this does not take into account whether the spot exchange rate is also below the target value (that is, in the appreciation part). For these two countries, the appreciation movements are also less volatile if they start in the depreciation part of the implicit target band. The opposite is true for Romania.

Furthermore, we can see that that the asymmetric effects of exchange rate misalignments, δ_2, are significant in all countries (see Table 3).[10] Negative deviations of the spot exchange rate from the target value (that is, spot exchange rate located in the appreciation area) increase the volatility of daily exchange rates significantly. This finding indicates that the target zones are less credible in the appreciation part in these countries.[11] By contrast, we can see that the persistence of exchange rate shocks is lower during the appreciation periods. Only in Romania we can find as before that the exchange rate volatility is persistent in the appreciation area of the implicit target zone.

Additionally, we performed several sensitivity analyses similar to those for GARCH models. First, the time-varying implicit target rate was proxied by Hodrick–Prescott filter instead of moving average. Next, EGARCH model was applied to assess the asymmetries further. Overall, the results from sensitivity analysis confirm those of baseline specification.

Fig. 3 documents the asymmetrical relationship between the exchange rate volatility and the relative level of exchange rates as compared to the targets based on the results reported in Table 3.

[10] Correspondingly, the development pattern of exchange rate volatility is similar to that presented in Fig. 2. Detailed results are available upon request from authors.

[11] Note that, by definition, the opposite is true for the depreciation side of the target zone.

Table 3
Asymmetric estimates of the effect of spot position to target value on conditional volatility (TARCH models), January 1999 to October 2006

Country	Czech Republic	Hungary	Poland	Slovakia	Romania
μ	−0.019*** (−2.641)	0.004 (0.835)	−0.016 (−1.318)	−0.012* (−1.903)	0.018* (1.897)
γ_1	0.000*** (4.843)	0.000*** (−11.292)	0.000*** (4.667)	0.000*** (4.766)	0.000 (0.104)
γ_2	0.054*** (4.756)	0.140*** (17.100)	0.100*** (8.402)	0.089*** (8.229)	0.088*** (13.207)
γ_3	0.879*** (58.196)	0.893*** (172.148)	0.893*** (81.045)	0.866*** (63.517)	0.879*** (129.651)
γ_4	0.017 (1.265)	−0.086*** (−6.816)	−0.085*** (−5.192)	−0.018 (−1.284)	0.054*** (3.785)
δ_1	1.200*** (3.186)	1.760*** (19.882)	1.100 (1.512)	0.866*** (3.898)	1.730*** (5.208)
δ_2	3.840*** (5.276)	2.330*** (18.062)	2.820*** (4.307)	1.660*** (6.090)	1.910*** (4.101)
$\gamma_2 + \gamma_3 = 1$	0.932*** [0.000]	1.034*** [0.000]	0.992*** [0.000]	0.955*** [0.000]	0.967*** [0.000]
$\gamma_2 + \gamma_3 + \gamma_4 = 1$	0.950*** [0.000]	0.948*** [0.000]	0.907*** [0.000]	0.937*** [0.000]	1.021* [0.053]
SIC	−8.611	−8.560	−7.392	−9.083	−7.629
N	20028	20028	20028	20028	20028
L-B(10), RES	5.709 [0.839]	11.321 [0.333]	15.462 [0.051]	11.773 [0.226]	11.948 [0.289]
L-B(10), SQRES	4.440 [0.925]	1.577 [0.999]	13.125 [0.108]	4.264 [0.893]	6.945 [0.731]

Notes: we report z-statistics in parentheses and p-values of the Wald test that $\gamma_2 + \gamma_3 = 1$ and $\gamma_2 + \gamma_3 + \gamma_4 = 1$, as well as the Ljung–Box Q-statistics of the 10th lag for standard and squared residuals in brackets. For clarity of the discussion in the text, coefficients μ and δ are multiplied by 100 and 10^4, respectively.
* Denote significance at 1%.
** Denote significance at 5%
*** Denote significance at 10%.

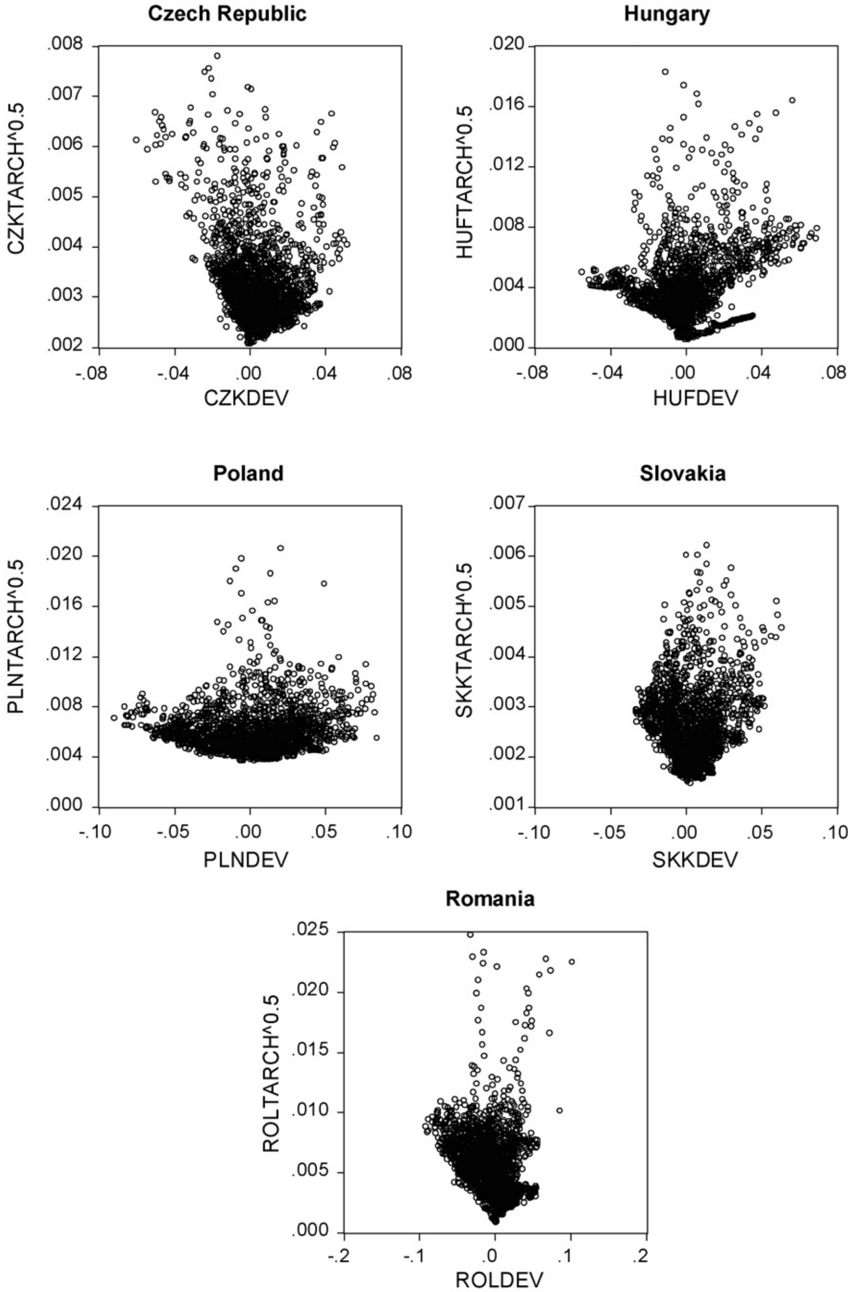

Fig. 3. Conditional standard deviation and the deviation of spot exchange rate from the target rate, January 1999 to October 2006.

On the one hand, we can see that the conditional variance increases as the actual exchange rate deviates from its implicit target rate. This relationship seems to be asymmetric in all NMS except for Poland. In particular, the relationship between the exchange rate deviations from the target value is steeper in the appreciation area.

On the other hand, the points with the extreme conditional volatility are often observed around the target values of exchange rates, which is consistent with the target zone model. However, there are also observations with comparably high values of exchange rate volatility in the depreciation area of the implicit target zones, especially in Hungary, Slovakia and Romania.

5. Conclusions

We analyze high-frequency exchange rate dynamics in selected NMS that introduced inflation targeting regime. Our sample consists of five NMS (Czech Republic, Hungary, Poland, Slovakia and Romania). These countries maintained relatively free exchange rates between 1999 and 2006.

Following the target zone model by Krugman (1991), we examine the exchange rate volatility in connection to the estimated target exchange rate. We estimate GARCH models of daily exchange rate volatility. We find that the volatility is quite persistent in all NMS. In addition, the exchange rate is more volatile if it is far away from its implicit target rate in all analyzed countries. This indicates that there may be implicit exchange rate target zones in some of these countries, however, which suffer under insufficient credibility. Finally, our TARCH results point to systematic asymmetries in the exchange rate volatility in the NMS. The volatility of exchange rate is significantly more pronounced especially during the periods of exchange rate appreciation in all analyzed countries.

Given the persistent volatility of exchange rates in all analyzed NMS, the policy of inflation targeting seems to be an attractive option before the euro adoption. Our sensitivity analysis for the recent period (2004–2006) showed that Poland and the Czech Republic, that is, the countries with the longest experience with inflation targeting, have also experienced less volatility of exchange rate with respect to its medium-term target level.

Acknowledgements

We thank two anonymous referees, Paul de Grauwe, Evžen Kočenda, Mikael Bask, Iikka Korhonen, Gunter Schnabl, Matúš Senaj, Juraj Valachy, Bas van Aarle and workshop participants at the CESifo conference on euro area enlargement, seminar participants at the National Bank of Slovakia and BOFIT, as well as Eiji Ogawa, Mariusz Krawczyk, Seiichi Fujita, and participants of the EU Studies Workshop at the Kobe University for helpful comments. We appreciate research assistance by Mirja Bächle and Yin Xia. The views expressed here do not necessarily represent those of the Czech National Bank. Horváth acknowledges the support from the Czech Science Foundation grant "402/05 H510 Economic Theory of Political Markets".

Appendix A. Sensitivity analysis

Tables A.1 and A.2.

Table A.1
Estimates of the effect of the spot position to the target value on conditional volatility (GARCH Models), EU Membership Sub-Sample, May 2004 to October 2006

Country	Czech Republic	Hungary	Poland	Slovakia	Romania
μ	−0.022** (−2.124)	−0.003 (−0.222)	−0.049** (−2.380)	−0.018* (−1.654)	−0.007 (−0.565)
γ_1	0.000* (1.694)	0.000 (0.990)	0.000 (1.552)	0.000** (2.530)	0.000 (0.276)
γ_2	0.064*** (4.400)	0.080*** (4.486)	0.064*** (3.292)	0.073*** (5.024)	0.158*** (11.539)
γ_3	0.911*** (45.785)	0.900*** (47.926)	0.873*** (18.574)	0.900*** (52.369)	0.837*** (100.242)
δ	−0.033 (−0.053)	1.900*** (2.993)	2.920 (1.424)	0.526** (2.528)	3.510*** (7.453)
$\gamma_2 + \gamma_3 = 1$	0.975* [0.067]	0.980** [0.023]	0.937* [0.076]	0.973*** [0.000]	0.994 [0.535]
SIC	−8.910	−8.210	−7.663	−9.123	−8.183
N	638	638	638	638	638
L-B(10), RES	18.202* [0.052]	16.774* [0.080]	13.424 [0.201]	10.748 [0.293]	4.428 [0.926]
L-B(10), SQRES	16.696* [0.081]	13.526 [0.196]	8.466 [0.583]	2.436 [0.983]	4.867 [0.900]

Notes: we report z-statistics in parenthesis and p-values of the Ljung–Box Q-statistics of the 10th lag for standard and squared residuals in brackets. For clarity of the discussion in the text, the coefficients μ are multiplied by 100.

* Denote significance at 10%.

** Denote significance at 5%.

*** Denote significance at 1%.

Table A.2
Estimates of the effect of the spot position to the target value on conditional volatility (TARCH Models), EU Membership Sub-Sample, May 2004 to October 2006

Country	Czech Republic	Hungary	Poland	Slovakia	Romania
μ	−0.032*** (−2.997)	0.012 (0.768)	−0.048** (−2.339)	−0.027** (−2.458)	−0.016 (−1.244)
γ_1	0.000 (1.137)	0.000** (2.080)	0.000** (2.256)	0.000 (−1.536)	0.000 (0.218)
γ_2	−0.004 (−0.235)	0.144*** (4.404)	0.003 (0.391)	0.013** (2.226)	0.045*** (2.917)
γ_3	0.058** (2.334)	−0.152*** (−4.176)	−0.027 (−1.506)	−0.018*** (−2.810)	0.212*** (5.389)
γ_4	0.947*** (45.627)	0.893*** (34.852)	0.982*** (119.149)	0.986*** (217.220)	0.844*** (66.309)
δ_1	0.380 (0.883)	3.680** (2.363)	1.200 (1.640)	0.312** (2.479)	2.510*** (6.539)
δ_2	4.320*** (2.906)	−2.030 (−1.370)	3.760*** (3.873)	1.140*** (5.922)	5.160*** (5.629)
$\gamma_2 + \gamma_3 = 1$	0.943*** [0.000]	1.036 [0.106]	0.985** [0.012]	0.999 [0.578]	0.888*** [0.000]
$\gamma_2 + \gamma_3 + \gamma_4 = 1$	1.001 [0.961]	0.884 [0.961]	0.958*** [0.006]	0.981*** [0.000]	1.100*** [0.000]
SIC	−8.923	−8.213	−7.674	−9.133	−8.215
N	638	638	638	638	638
L-B(10), RES	17.704 [0.060]	16.306 [0.091]	13.397 [0.202]	12.111 [0.278]	4.083 [0.944]
L-B(10), SQRES	15.899 [0.103]	14.184 [0.165]	10.340 [0.411]	9.434 [0.492]	2.715 [0.987]

Notes: we report z-stats in parenthesis and p-values of the Wald test that $\gamma_2 + \gamma_3 = 1$ and $\gamma_2 + \gamma_3 + \gamma_4 = 1$, as well as the Ljung–Box Q-statistics of the 10th lag for standard and squared residuals in brackets. For clarity of the discussion in the text, coefficients μ and δ are multiplied by 100 and 10^4, respectively.

* Denote significance at 10%

** Denote significance at 5%.

*** Denote significance at 1%.

References

Baillie, R.T., Bollerslev, T., 1989. The message in daily exchange rates: A conditional-variance tale. J. Business Econ. Stat. 7, 297–305.
Bask, M., Fidrmuc, J., 2006. Fundamentals and technical trading: behavior of exchange rates in the CEECs. Discussion Paper 10/2006. Bank of Finland, Helsinki.
Bessec, M., 2003. The asymmetric exchange rate dynamics in the EMS: A time-varying threshold test. Eur. Rev. Econ. Finance 2, 3–40.
Borghijs, A., Kuijs, L., 2004. Exchange rates in Central Europe: a blessing or a curse? IMF Working Paper WP/04/2. Washington, DC.
Calvo, G., Reinhart, C., 2002. Fear of floating. Q. J. Econ. 117, 379–408.
Chmelarova, V., Schnabl, G., 2006. Exchange rate stabilization in developed and underdeveloped capital markets. ECB Working Paper 636. Frankfurt/Main.
Chung, C.S., Tauchen, G., 2001. Testing target-zone models using efficient method of moments. J. Business Econ. Stat. 19, 255–269.
Coricelli, F., Jazbec, B., Masten, I., 2006. Exchange rate pass-through in EMU acceding countries: empirical analysis and policy implications. J. Banking Finance 30, 1375–1391.
Crespo-Cuaresma, J., Égert, B., MacDonald, R., 2005a. Non-linear exchange rate dynamics in target zones: a bumpy road towards a honeymoon. Williams Davidson Institute Working Paper 771. Ann Arbor, MI.
Crespo-Cuaresma, J., Fidrmuc, J., Silgoner, M.A., 2005b. On the road: the path of Bulgaria, Croatia and Romania to the EU and the euro. Europe-Asia Stud. 57, 843–858.
De Grauwe, P., Schnabl, G., 2005. Nominal versus real convergence—EMU entry scenarios for the new member states. Kyklos 58, 537–555.
Edison, H.J., Miller, M.H., Williamson, J., 1987. On evaluating and extending the target zone proposal. J. Policy Model. 9, 199–227.
Égert, B., Lommatzsch, K., 2004. Equilibrium exchange rates in transition: the tradable price-based real appreciation and estimation uncertainty. William Davidson Institute Working Paper 676. Ann Arbor, MI.
Égert, B., 2007. Central bank interventions, communication and interest rate policy. J. Comp. Econ. 35, 387–413.
Égert, B., Komárek, L., 2006. Foreign exchange interventions and interest rate policy in the Czech Republic: hand in glove? Econ. Syst. 30, 121–140.
Eichengreen, B., 1994. International Monetary Arrangements for the 21st Century. The Brookings Institution, Washington, DC.
Engle, R.F., Gau, Y., 1997. Conditional volatility of exchange rates under a target zone. Working Paper 06/97. University of California, San Diego, CA.
Engle, R.F., Ng, V.K., 1993. Measuring and testing the impact of news on volatility. J. Finance 48, 1022–1082.
Fidrmuc, J., Korhonen, I., 2006. Meta-analysis of the business cycle correlation between the euro area and the CEECs. J. Comp. Econ. 34, 518–537.
Frömmel, M., Schobert, F., 2006. Exchange rate regimes in Central and East European countries: deeds vs. words. J. Comp. Econ. 34, 467–483.
García-Solanes, J., Sancho-Portero, F.I., Torrejón-Flores, F., 2008. Beyond the Balassa–Samuelson effect in some new member states of the European Union. Economic Systems 32, 17–32.
Geršl, A., Holub, T., 2006. Foreign exchange interventions under inflation targeting: the Czech experience. Contemp. Econ. Policy 24, 475–491.
Ghosh, A.R., Gulde, A.M., Wolf, H.C., 2003. Exchange Rate Regimes: Choices and Consequences. The MIT Press, Cambridge.
Glosten, L.R., Jaganathan, R., Runkle, D., 1993. On the relation between the expected value and the volatility of the normal excess return on stocks. J. Finance 48, 1779–1801.
Horváth, R., 2007. Ready for euro? Evidence on EU new member states. Appl. Econ. Lett. 14, 1083–1086.
Ito, T., Yabu, T., 2007. What promotes Japan to intervene in the forex market? A new approach to a reaction function. J. Int. Money Finance 26, 193–212.
Kempa, B., Nelles, M., 1999. The theory of exchange rate target zones. J. Econ. Surv. 13, 173–210.
Krugman, P., 1991. Target zone and exchange rate dynamics. Q. J. Econ. 56, 669–682.
Kočenda, E., 1998. Altered band and exchange volatility. Econ. Trans. 6, 173–181.
Kočenda, E., Kutan, A.M., Yigit, T.M., 2006. Pilgrims to the Eurozone: how far, how fast? Econ. Syst. 30, 311–327.

Kočenda, E., Valachy, J., 2006. Exchange rate volatility and regime change: Visegrad comparison. J. Comp. Econ. 34, 727–753.

MacDonald, R., Wójcik, C., 2008. Catching-up and inflation differentials in a heterogeneous monetary union: some implications for the euro area and new EU member states. Econ. Syst. 32, 4–16.

Markiewicz, A., 2006. Choice of exchange rate regime in transition economies: an empirical analysis. J. Comp. Econ. 34, 484–498.

Nell, M., 2004. Monetary Policy in the Slovak Republic: Implicit Inflation Targeting and the Choice of an Optimal Exchange Rate Regime, 11. National Bank of Slovakia, BIATEC, 22–25.

NBS, 2004. Monetary Programme. National Bank of Slovakia, Bratislava.

Obstfeld, M., Rogoff, K., 1998. Foundations of International Macroeconomics. MIT Press, Cambridge, MA.

Sarno, L., Taylor, M.P., 2002. The Economics of Exchange Rates. Cambridge University Press, Cambridge.

Schnabl, G., 2008. Exchange rate volatility and growth in small open economies at the EMU periphery. Econ. Syst. 32, 70–91.

Williamson, J., 1985. The Exchange Rate System. Institute for International Economics, Washington, DC.

Zakoïan, J.M., 1994. Threshold heteroskedastic models. J. Econ. Dyn. Control 18, 931–944.