On Asymmetry of Exchange Rate Volatility in New EU Member and Candidate Countries

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Abstract—In this paper, we examine the exchange rate volatility in selected new EU Member States (Czech Republic, Hungary, Poland, Slovakia) and candidate countries (Croatia, Romania, Turkey) using TARCH model and daily data from the period May 2004 – December 2006. Besides the volatility estimation, the paper analyzes the asymmetric effects. The results suggest that some symptoms of asymmetry were found in all exchange rates except for CZK/EUR. However, the most distinct effects are evident in Slovakia and Turkey where the appreciation of the national currency and the appreciation-side deviation from the target exchange rate contribute significantly to the increase in the exchange rate volatility.

Keywords—asymmetry, European Union, exchange rate volatility, TARCH models.

I. INTRODUCTION

All new member states (NMS) of the European Union (EU) are supposed to adopt the euro in the future. However, according to the Maastricht Treaty, the euro implementation is conditioned on the fulfillment of several convergence criteria. One of them is focused on exchange rate stability (ERSC) and goes hand in hand with compulsory participation in the European Exchange Rate Mechanism II (ERM II) for at least two years prior to the assessment of the ERSC fulfillment. Moreover, no downward realignment of central parity of the national currency vis-à-vis euro (devaluation) is possible within the two-year evaluation period. Additionally, fulfillment of the ERSC requires the exchange rate to have been maintained within a fluctuation margin around the central parity "without severe tensions". Although the standard fluctuation band of ERM II is ± 15%, according to the European Central Bank (ECB) and European Commission, maintaining the exchange rate within the asymmetric margin of 15% on the appreciation side and 2.25% on the depreciation side will be probably demanded for successful fulfillment of the ERSC [4].

Knowing this fact, it is essential to analyze the exchange rate volatility and the asymmetric effects in particular. We distinguish two form of asymmetry in the exchange rate volatility. First, we can often see that the exchange rate volatility is different along positive and negative trends. More concretely, the downward movements are usually associated with higher volatility. Second, the volatility may rise with the increasing deviation of the spot exchange rate from the target level (central parity). Consequently, the depreciation deviation can lead to a higher volatility than the appreciation deviation of the same size and vice versa.

Therefore, the aim of the paper is to estimate exchange rate volatility and to assess asymmetric effects in the context of ERSC. The main question addressed is whether the volatility increases when the national currency is depreciating and the depreciation deviation from the target exchange rate is growing.

For this purpose we apply Threshold Autoregressive Conditional Heteroscedasticity (TARCH) models on daily exchange rates of national currencies of selected NMS (Czech Republic, Hungary, Poland, Slovakia) and that time candidate countries (Croatia, Romania, Turkey) vis-à-vis the euro from the period May 1, 2004 – December 31, 2006.

The paper is structured as follows. The next section presents the model specification and describes the data used. Section III provides results of the empirical estimation and some commentary. The paper ends with Section IV in which the main findings are summarized and conclusions drawn.

II. DATA AND MODEL SPECIFICATION

The time span chosen begins on day when 10 countries joined the EU (four of them included in the analysis) and ends on day preceding the day of Bulgaria and Romania entry. The data were extracted from the Eurostat Economy and Finance database and are constructed on a five-day-week basis. This yields to 687 observations in total. The elementary descriptive statistics is presented in Table I.

Using the coefficient of variation defined as the ratio of the standard deviation and the mean we can see that Romanian leu (RON) is the least volatile currency followed by Slovak koruna (SKK), Hungarian forint (HUF), Czech koruna (CZK), Polish zloty (PLN) and Croatian kuna (HRK). On the other hand, Turkish lira (TRY) exhibits the highest volatility, which reflects a turbulent development depicted in Fig. 1. The left part of Fig. 1 shows the exchange rate development in NMS and clearly reveals a nominal appreciation of CZK, PLN and SKK. After a substantial depreciation in the first half of 2006, HUF remained almost unchanged comparing with the initial

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TABLE I

DESCRIPTIVE STATISTICS

	CZK/EUR	HUF/EUR	PLN/EUR	SKK/EUR	RON/EUR	HRK/EUR	TRY/EUR
Mean	29.67610	254.2467	4.074107	38.40127	7.386238	3.694291	1.765969
Median	29.60800	251.0700	4.018300	38.51000	7.374000	3.614400	1.776300
Maximum	32.55000	283.3500	4.791900	40.35000	7.669500	4.125700	2.133500
Minimum	27.41800	241.5300	3.757300	34.34900	7.237100	3.351000	1.555000
Standard deviation	1.274758	9.989039	0.236368	1.209269	0.087987	0.224050	0.124509
Skewness	0.334424	1.189051	1.066529	-0.621745	0.778020	0.889345	0.176604
Kurtosis	1.853493	3.381601	3.429247	3.514638	3.153642	2.266858	2.076072
Jarque-Bera test	50.43262 [0.0000]	166.0534 [0.0000]	135.5162 [0.0000]	51.84325 [0.0000]	69.98421 [0.0000]	105.9479 [0.0000]	28.00668 [0.0000]
Observations	687	687	687	687	687	687	687

Source: Author's calculation based on data from Eurostat

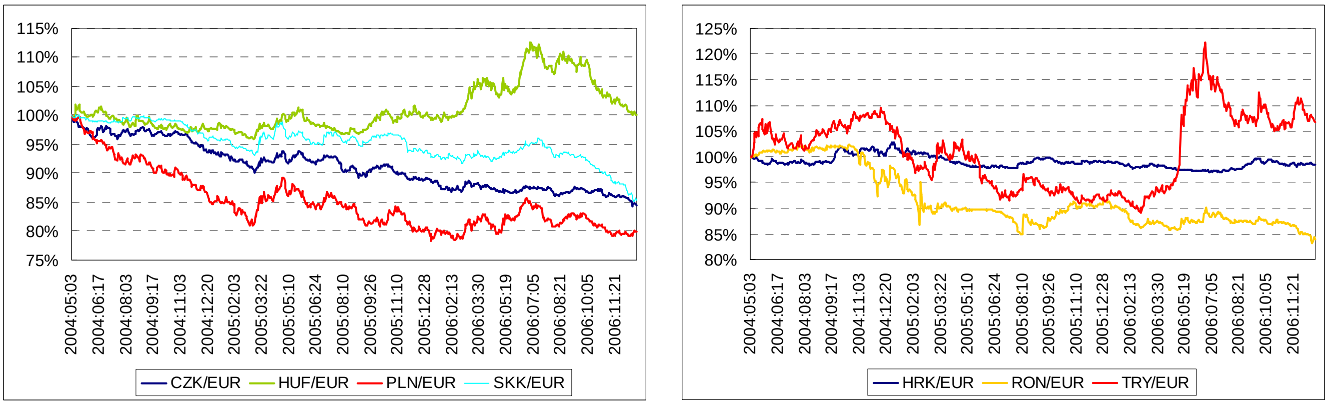

Fig. 1 Exchange rate development (May 1, 2004 – December 31, 2006, in %, May 1, 2004 as a base)

Source: Author's calculation

value in May 2004. The right graph illustrates, besides TRY, a stable development of HRK and nominal appreciation of RON.

Assessment of the second type of asymmetry in the exchange rate volatility requires implementation of the target exchange rate into computation. Since the target level was explicitly set in none of the countries analyzed during the entire period we substituted it by an implicit target exchange rate. Following [3], [6] and [8] we approximated the target exchange rate by 120th moving average mode. This time varying target exchange rate is computed as the average of exchange rates from ± 60 trading days around the day of observation. Since we were able to use also the exchange rates prior May 1, 2004 the moving average computation restricts our estimation period only on the most recent side. To conserve the space neither descriptive statistics nor graphical illustration of the moving averages are reported here but they are available on a request.

To test empirically for exchange rate volatility a Generalized Autoregressive Conditional Heteroscedasticity (GARCH) model is usually employed in recent studies. The GARCH model was originally introduced in [2]. However, this specification makes no difference between positive and negative innovations in their impact on volatility. Whereas the size is the key aspect of innovations their direction is treated in no manner. The theory of leverage effect first described in [1] provoked [12] and [7] to propose the TARCH model to analyze asymmetric volatility. This model comprises a leverage term that allows for the asymmetric impacts of good and bad news (positive and negative innovations) on volatility.

In accordance with our aim to assess two types of asymmetry we augment the standard TARCH model by the parameters reflecting the deviation of the spot exchange rate from the target level. Correspondingly, our estimation specification of the TARCH(1,1) model is as follows:

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

$$\begin{aligned}\sigma_{jt}^2 = \gamma_{j1} + \gamma_{j2}\xi_{jt-1}^2 + \gamma_{j3}\sigma_{jt-1}^2 + \gamma_{j4}D_{jt-1}^{arch}\xi_{jt-1}^2 + \\ + \delta_{j1}\left|s_{jt-1}^D - s_{jt-1}^F\right| + \delta_{j2}D_{jt-1}^S\left|s_{jt-1}^D - s_{jt-1}^F\right| + \omega_{jt}\end{aligned}, \tag{2}$$

where s_{jt}^D denotes the spot exchange rate of the national currency j vis-à-vis the euro in the time t. s_{jt}^F is the time varying target exchange in the form of the above defined moving average. Besides the constant term, the mean equation (1) does not include any other explanatory variable. The constant term μ_t shows the average rate of depreciation or appreciation. The error term, ξ_{jt}, of the mean equation (1) is assumed to have a time varying conditional variance, σ^2, specified by equation (2).

Furthermore, equation (2) comprises the ARCH term, ξ_{jt-1}, that reflects the impacts of news from previous periods that

TABLE II
ESTIMATES OF TARCH MODELS

	CZK/EUR	HUF/EUR	PLN/EUR	SKK/EUR	RON/EUR	HRK/EUR	TRY/EUR
μ	-0.0003***	-0.0000	-0.0005***	-0.0002***	-0.0000	-0.0001	-0.0001
	(-3.3189)	(-0.6314)	(-3.0538)	(-2.7963)	(-0.8472)	(-1.4153)	(-0.4112)
γ_1	0.0000	-0.0000	0.0000	-0.0000***	-0.0000	0.0000**	0.0000
	(1.1187)	(-1.0329)	(0.3324)	(-4.0990)	(-1.0013)	(2.2491)	(0.2262)
γ_2	0.0148	0.0727***	-0.0055	-0.0141***	0.0595***	0.0416	0.0216
	(0.7570)	(4.6310)	(-0.6941)	(-3.0955)	(2.6514)	(1.2085)	(1.5254)
γ_3	0.9192***	0.9816***	0.9855***	0.9991***	0.9524***	0.7970***	0.9669***
	(35.470)	(173.83)	(127.85)	(135.64)	(50.199)	(10.511)	(63.726)
γ_4	0.0396	-0.1153***	-0.0245	-0.0321*	-0.0468	0.2511**	-0.0424**
	(1.2864)	(-3.7491)	(0.3027)	(-1.9494)	(-1.6383)	(2.1947)	(-2.0517)
δ_1	0.581	-2.110**	1.970	4.320***	1.260*	3.620	5.230*
	(0.4410)	(-2.5664)	(0.7595)	(6.8557)	(1.8221)	(0.9026)	(1.8373)
δ_2	6.340	1.060	11.40**	11.80***	2.670**	17.50*	13.60**
	(1.6167)	(0.7226)	(2.4699)	(6.5310)	(2.4598)	(1.6651)	(2.5500)
$\gamma_2 + \gamma_3 = 1$	0.9340***	1.0543***	0.9910**	0.9850	1.0119	0.8386***	0.9885
	[0.0063]	[0.0002]	[0.0171]	[0.1460]	[0.5103]	[0.0068]	[0.3024]
$\gamma_2 + \gamma_3 + \gamma_4 = 1$	0.9736	0.9390***	0.9665**	0.9529***	0.9651***	1.0897	0.9461***
	[0.2523]	[0.0007]	[0.0487]	[0.0000]	[0.0061]	[0.2356]	[0.0027]

Source: Author's calculation based on data from Eurostat

Notes: z-statistics are reported in parentheses and p-values of the Wald test that $\gamma_2 + \gamma_3 = 1$ and $\gamma_2 + \gamma_3 + \gamma_4 = 1$ are reported in brackets. ***, **, and * denote significance on 1 percent, 5 percent, and 10 percent, respectively. For clarity of the estimates and discussion in the text, values of coefficients δ_1 and δ_2 are multiplied by 10^5.

affect exchange rate volatility, and the GARCH term, σ^2_{jt-1}, that measures the impact of the forecast variance from previous periods on volatility [9]. The core of the TARCH term is the dummy variable, D^{arch}_{jt-1}, that equals 1 in the case of a negative shock (ξ_{jt}<0) and zero otherwise (ξ_{jt}>0). Thus, a negative value of the coefficient γ_{j4} means that the negative innovations (appreciation of the national currency if the direct quotation applies) tend to increase the subsequent volatility more than do the positive shocks (depreciation of the national currency) of an equal magnitude. Likewise, the dummy variable, D^{S}_{jt-1}, is equal to 1 if the spot exchange rate is lower than the target exchange rate, that is, if the exchange rate is in the appreciation part of the target zone. Consequently, the positive value of coefficients δ_{j1} and δ_{j2} indicates that the exchange rate volatility increases as the spot exchange rates departs from the target value. More concretely, the positive value of coefficient δ_{j2} implies that the volatility increase is associated predominantly with the appreciation deviations from the target exchange rate.

III. EMPIRICAL RESULTS

As the first step of empirical analysis, all values of exchange rates and moving averages (both in direct quotes, i.e. price of one euro in units of national currency) were logged. Secondly, the augmented Dickey-Fuller (ADF) tests were applied to examine stationarity of the time series used. Although the results of ADF tests are not reported here, they confirm that all series are I(1). In other words, they are stationary in log first differences. Accordingly, the TARCH model defined in (1) and (2) is estimated for the log changes in exchange rate and moving average series. Results of the estimations for all exchange rates are summarized in Table II. The results provide some interesting insights.

First, the exchange rate volatility during the period analyze is presented in Fig. 2. We can observe some outbursts of volatility such us in March 2005 (almost all exchange rates) or in second quarter of 2006 (HUF, TRY). It is also evident that the conditional variance changed frequently in many countries. The group of currencies with the lowest and most stable

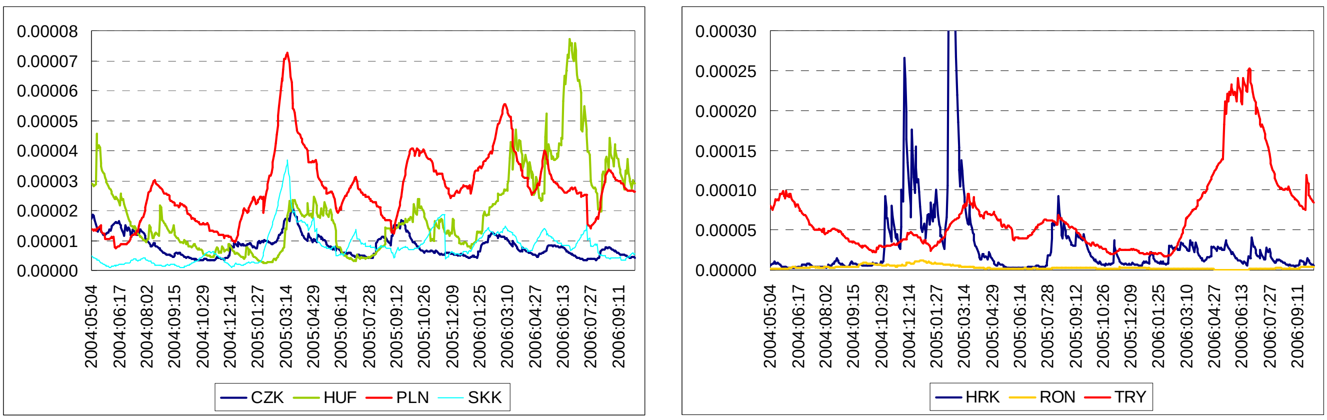

Fig. 2 Conditional standard deviation estimated from TARCH models
Source: Author's calculation

volatility comprises CZK, SKK and RON. On the contrary, the most volatile development was revealed in the exchange rate TRY/EUR and HRK/EUR during the fist third of the estimation period. Except for TRY, there were not substantial differences in the exchange rate volatility among NMS and candidate countries in the last year.

Concentrating on the estimation results in Table II, the values of coefficients μ show that three currencies of NMS (namely CZK, PLN and SKK) demonstrated a significant appreciation against the euro during the period analyzed. The remaining currencies did not possess any significant trend of appreciation or depreciation. Next, the ARCH term appears to be significant in the case of HUF, SKK and RON. While the further unanticipated news or surprises about volatility tend to increase the exchange rate risk in Hungary and Romania (positive signs of coefficient γ_2), the opposite effect was detected in Slovakia.

The GARCH term is strongly significant and present in all exchange rate series. Except for HRK, values of coefficient γ_3 are dimensionally large and very close to unity, which indicates a high degree of volatility persistence. The sum of the ARCH and GARCH term coefficients tells us about the convergence of the exchange rate to a steady state. If the sum is below unity there is an evidence of convergence. The closer is the sum to unity the slower convergence can be observed. However, estimation of two models (HUF, RON) led to the sum exceeding unity. Such a result documents no convergence of the exchange rate to a steady state.

The TARCH term capturing the first type of asymmetry in the exchange rate volatility is statistically significant if four

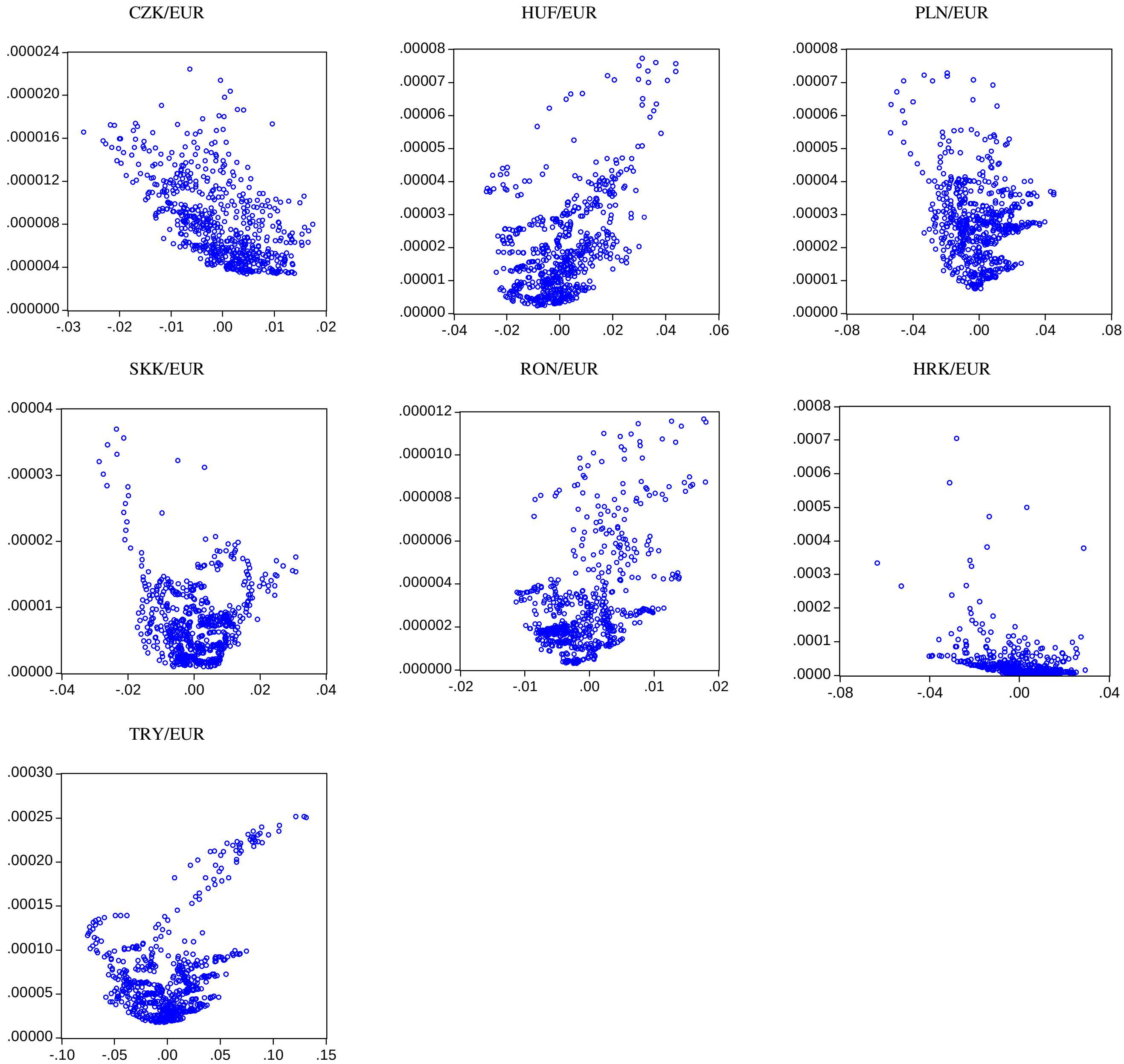

Fig. 3 Conditional variance and the deviation of spot exchange rate from the target rate
Source: Author’s calculation

models. Three coefficients γ_4 are negative (HUF, SKK, TRY) indicating that the increase in volatility is associated with appreciation of the currencies mentioned. On the other hand, the empirical evidence that the depreciation of the national currency leads to higher volatility is provided for Croatia. Consequently, except for HRK and CZK the sum of coefficients γ_2, γ_3 and γ_4 is lower than the sum of coefficients γ_2 and γ_3. This fact can be interpreted as the evidence of higher persistence of exchange rate shocks during the depreciation periods in majority of the countries analyzed.

The last two explanatory variables in the conditional variance equation capture the deviation of the spot exchange rate from the target level. As it is evident from Table II, the deviation from the implicit target rate has a significant impact on volatility in Hungary, Slovakia, Romania and Turkey. Except for Hungary, coefficients δ_1 are positive implying that the volatility increases as the distance from the target exchange rate magnifies. Thus, the implicit target is not credible and exchange rates do not act as shock absorbers. On the contrary, the increase in the deviation from the target rate has a reducing effect on the volatility of exchange rate HUF/EUR. In the Czech Republic, Poland and Croatia the impact of the deviation from implicit target proves to be insignificant. The second key term of our interest capturing the second type of asymmetry was found to be significant in five exchange rates (PLN, SKK, RON, HRK and TRY). All significant coefficients δ_2 have positive sign and, thus, document that the exchange volatility increases as national currencies appreciate and the spot exchange rate is below the target exchange rate. Apparently, the target zone is less credible in the appreciation part. By definition, the opposite is true for the depreciation part of the target zone. Assessing these findings in the context of ERSC, we can find them as favorable. In the evaluation of the ERSC fulfillment, the depreciation deviations from the ERM II central parity are treated more strictly than the appreciation tendencies. However, it must be noted that the estimation results should be verified in the environment of explicitly defined target exchange rate in the form of the ERM II central parity and respective target zone defined by the ERSC fluctuation band.

The asymmetrical linkages between exchange rate volatility and deviation from the implicit target rate are graphically illustrated in Fig. 3. The horizontal axes of the graphs represent the deviation as defined in (2) and the vertical axes depict the conditional variance estimated. We can see that the conditional variance increases as the spot exchange rate departs from the target level. Moreover, the extreme values of conditional variance can be observed along with negative deviations (appreciation part of the target zone) in the Czech Republic, Poland and Slovakia. Although Croatia does not show any clear pattern the extreme volatility observations go hand in hand with negative deviations as well. By contrast, the extreme exchange rate volatility occurred when the spot exchange rate was above its target (depreciation part of the target zone) in Hungary, Romania and Turkey.

IV. CONCLUSION

The paper aimed to estimate the exchange rate volatility in selected NMS and EU candidate countries and assess the effect of asymmetry in the volatility. The highest volatility was revealed in the exchange rate TRY/EUR. No substantial differences were found in the volatility of the remaining exchange rates. Regarding the asymmetry effects, both types of asymmetry were detected in Slovakia, Croatia and Turkey. The most consistent conclusion can be drawn for Slovakia and Turkey. The coefficients estimated suggest that the exchange rate volatility increases as the national currency appreciates and as the spot exchange rate deviates from its target level in the appreciation part of the target zone. This finding is essential particularly for Slovakia which started to fulfill ERSC in November 2005 when SKK entered into ERM II. Other exchange rates also demonstrate some asymmetry effects but their interpretation is not so straightforward. The only one exchange rate with no asymmetry identified is CZK/EUR. However, for a comprehensive assessment of the asymmetry the explicit target rate and target zone should be applied in the analysis.

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