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**Article**

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## **ASSESSMENT OF THE EXCHANGE RATE CONVERGENCE IN EURO-CANDIDATE COUNTRIES**



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### **Abstract**

This paper assesses the exchange rate convergence in selected euro-candidate countries using an alternative approach to official exchange rate stability convergence criterion. We apply various versions of correlation analysis on daily returns and implied GARCH volatility of nominal exchange rates of the euro, Czech koruna, Hungarian forint, Polish zloty, Romanian leu, Slovak koruna and Croatian kuna vis-à-vis US dollar. The results suggest that none of the euro-candidates' currencies achieved a sufficient degree of convergence. If anything, a majority of the currencies analyzed in the paper experienced a departure from convergence during the recent period.

**Keywords:** exchange rate, convergence, correlation, GARCH, euro-candidates

**JEL codes:** F31, F36

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### **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 dependent on the fulfillment of several convergence criteria. One of the required directions of convergence is the convergence of exchange rate development. The overwhelming majority of studies dealing with this issue focus mainly on the exchange rate stability criterion, assessment of its fulfillment, and participation of the national currency in the Exchange Rate Mechanism II (ERM II). Within this framework, the exchange rate volatility, equilibrium exchange rates or exchange market pressure are predominantly analyzed and various practical

implications for the exchange rate policy in the context of exchange rate stability criterion are provided.

Since this paper stems from a different concept, we refer a reader interested in the above-mentioned issues to the following studies. The process of the exchange rate stability criterion assessment is comprehensively analyzed in Égert and Kierzenkowski (2003). The authors come to the conclusion that although the standard fluctuation band of ERM II is  $\pm 15\%$ , according to the European Central Bank and European Commission, maintaining the exchange rate within the asymmetric margin of 15% on the appreciation side and 2.25% on the depreciation side for at least two years will most likely be demanded for successful fulfillment of the criterion. Volatility of the exchange rates including its asymmetric effect is estimated in e.g. Stavárek (2007a) or Fidrmuc and Horváth (2008). Some differences in the level of volatility recorded, as well as significance of the asymmetry are revealed among the NMS and candidate countries. Finally, the exchange market pressure is theoretically and empirically studied in Bielecki (2005), Poeck et al. (2007) or Stavárek (2007b). All studies point out that the most recent values of the exchange market pressure do not possess a threat for exchange rate stability and subsequent fulfillment of the respective convergence criterion.

This paper puts emphasis on alternative approach to the convergence of the exchange rate development that has not been applied as extensively in literature. It uses exchange rates of the euro and national currency of the euro-candidate country. Both exchange rates are quoted against the third currency that is not and will not be a part of the Eurozone. The higher the correlation between these two exchange rates the higher the degree of convergence in the exchange rate development between the particular euro-candidate country and the Eurozone. However, the correlation analysis of the exchange rate development does not provide a complete picture of the convergence since the volatility of the exchange rate is not taken into account. Therefore, we apply Generalized Autoregressive Conditional Heteroscedasticity (GARCH) models to generate time series of the exchange rate volatility and carry out correlation analysis with these volatility data as well. Besides the traditional simple correlation analysis we also use a dynamic version of the analysis based on calculation of the rolling correlation coefficient.

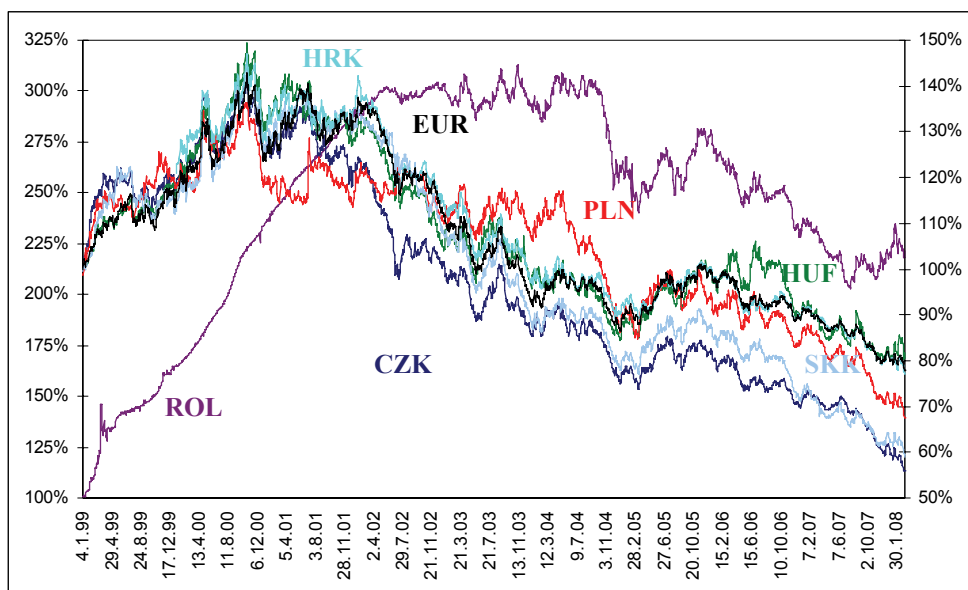
Thus, the aim of this paper is to estimate various alternative measures of the correlation coefficients between exchange rates of five NMS (Czech Republic, Hungary, Poland, Romania, and Slovakia) vis-à-vis US Dollar and the exchange rate of the euro vis-à-vis US Dollar (USD). Croatia, as a representative of EU-candidate countries, is also included in the analysis. Based on the results obtained, we will assess and compare the level of the achieved exchange rate development convergence.

The paper is structured as follows. First, the exchange rate development of the analyzed currencies is described along with the development and changes of the

exchange rate arrangements. Next, we discuss the empirical methods applied and provide the estimation results. Finally, the main findings of the analysis are summarized.

### Development of the exchange rate and exchange rate arrangement

The indispensable part of the convergence analysis is the graphical illustration of the exchange rate development. Figure 1 depicts development of all seven exchange rates analyzed during the period January 1999 – February 2008. The data used are on a daily basis and were drawn from the European Central Bank and national central banks databases. It is evident that Croatian kuna (HRK), Czech koruna (CZK), euro (EUR), Hungarian forint (HUF) and Slovak koruna (SKK) followed a very similar development path. The Polish zloty (PLN) witnessed a slightly different development, particularly during the period 2001 – 2003.



**Figure 1 Exchange rate development against USD**

*Source: Author's calculation*

*Note: ROL on the left axis, all other currencies on the right axis*

The resembling development is reflected in one important feature – all currencies mentioned appreciated against USD during the period analyzed. However, the magnitude of appreciation differs among currencies. The currency with the highest appreciation (44.13%) is CZK followed, with a small gap, by SKK (41.17%). The remaining currencies achieved substantially lower rate of appreciation, namely

PLN (32.57%), HRK (22.96%), EUR (22.24%) and HUF (18.34%). However, the dataset also includes one currency with very exceptional development against USD. It is Romanian leu (ROL) and its development is presented separately in special sub-figure. ROL is the only currency with total depreciation (-121.39%). This can be primarily attributed to the exchange rate regime applied by the Romanian central bank until the end of 2001.

Analyzing the general picture of the exchange rate development, one can distinguish three specific sub-periods. The first sub-period is bounded by January 1999 on one side and November 2000 on the other side. During this period of time all currencies experienced depreciation against USD when exchange rates peaked at levels around 140% of their initial values (225% for ROL). The exchange rate development of all currencies was very alike at that time as the difference between the most depreciated (HUF) and least depreciated currency (PLN), ignoring ROL, was only 13.66 percentage points on 30 November 2000.

The second sub-period covers the time span from December 2000 to December 2004. This sub-period can be distinguished by a gradual process of appreciation against USD. However, some deviations from the general trend can be found. First, CZK speeded up its appreciation in July 2001 – July 2002. This widened the gap between CZK and the remaining currencies. Second, PLN did not share the common appreciation trend in January 2001 – April 2004 as PLN remained almost unchanged experiencing only some marginal fluctuations on both appreciation and depreciation side.

The third sub-period lasted for rest of the time under consideration, i.e. January 2005 – February 2008. In 2005 one can recognize a clear depreciation trend that peaked in November. Since then all currencies have been consistently appreciating against USD. However, HUF continued with its decline over the first half of 2006 reflecting the increased risks originating from unsustainable fiscal deficit and political instability. ROL also went through a wave of depreciation in August 2007 – January 2008. The prevailing appreciation development differed in pace among currencies. Whereas SKK recorded a substantial appreciation in the last quarter of 2006, CZK and PLN were appreciating remarkably over the last 8 months analyzed. As a result of these developments, the gap between the most appreciated and the least appreciated currencies widened significantly during the third sub-period (15.2 percentage points on 3 January 2005 comparing with 25.8 points on 29 February 2008).

Interpretation of the correlation analysis results may be misleading if differences in exchange rate regimes are not taken into account. Therefore, next follows a review of exchange rate regimes applied in the countries analyzed. Besides the regimes used over the period under consideration, we also include regimes from the preceding period aiming to provide a comprehensive picture about changes in the

countries' exchange rate policies. The overview of exchange rate arrangements applied is reported in Table 1.

After gaining independence in January 1993, the Czech Republic adopted a tight peg of CZK to a basket of currencies (65% DEM, 35% USD). The initially narrow band  $\pm 0.5\%$  was widened to  $\pm 7.5\%$  in February 1996. The financial crisis that hit the Czech Republic in the first half of 1997 resulted in a shift of the exchange rate regime towards managed floating in May 1997. This arrangement has been applied since then; and in combination with inflation targeting since 1998.

After a one and half year episode with a crawling peg, Croatia has been practicing a tightly managed floating. Currently, Croatia uses EUR as the reference currency and exchange rate anchor. However, the de facto exchange rate policy of the Croatian National Bank can be characterized as a corridor of about  $\pm 4\%$  around the hypothetical central rate of 7.5 HRK/EUR (Barisitz, 2007, 85).

Hungary initially opted for a crawling peg in which HUF was pegged to the basket made up of ECU (70%) and USD (30%) and allowed to fluctuate within a narrow band  $\pm 2.25\%$  around the gradually devaluating central rate. In January 2000, the currency basket was substituted by EUR; and the bandwidth was widened to  $\pm 15\%$  in May 2001. The crawling band was abandoned in October 2001. Since then, Hungary has adopted a fixed parity regime against EUR with  $\pm 15\%$  margin along with the inflation targeting strategy. On 26 February 2008, however, National Bank of Hungary introduced free floating as the new official exchange rate arrangement.

Poland, at the initial stage of transformation process, chose a narrow crawling peg to the currency basket (45% USD, 35% DEM, 10% DEM, 5% FRF, 5% CHF) and applied this regime until the end of 1998. The fluctuation band was widened in three steps and the basket structure was adjusted in early 1999. In April 2000 the crawling peg was replaced by free floating that is applied concurrently with inflation targeting.

Romania used a managed floating regime for a long period of time to drive nominal depreciation of ROL. This arrangement was sometimes characterized as de facto implicit crawling band. USD was the reference currency until the end of 2001. Over the period 2002-2004 ROL was linked to EUR/USD basket. The EUR has been the only reference currency since early 2005. In August 2005 National Bank of Romania started with implementation of inflation targeting and loosening of the managed floating regime (Barisitz, 2007, 90).

Slovakia originally pegged SKK to the basket of DEM and USD and maintained a narrow band of  $\pm 1.5\%$ . Widening of the band in January 1997 was followed by the introduction of managed floating in October 1998. Since early 2005 managed floating was coupled with inflation targeting. In November 2005 Slovakia entered into ERM II as the first of the countries analyzed. Two and half years later, in April 2008, the Slovak government officially asked the European Commission for assessment of the convergence criteria fulfillment.

**Overview of the exchange rate arrangements in analyzed countries**

Table 1

<p><b>Czech Republic</b>                      Peg to currency basket (65% DEM, 35% USD) with band <math>\pm 0.5\%</math>                      Peg to currency basket (65% DEM, 35% USD) with band <math>\pm 7.5\%</math>                      Managed floating  <i>Inflation targeting since 01/98</i></p>	<p>05/93 – 02/96                      02/96 – 05/97                      05/97 –</p>
<p><b>Croatia</b>                      Crawling peg                      Tightly managed floating with reference currency</p>	<p>03/92 – 10/93                      10/93 –</p>
<p><b>Hungary</b>                      Crawling peg to currency basket (70% ECU, 30% USD) with band <math>\pm 2.25\%</math>                      Crawling peg to currency basket (70% DEM, 30% USD) with band <math>\pm 2.25\%</math>                      Crawling peg to EUR with band <math>\pm 2.25\%</math>                      Crawling peg to EUR with band <math>\pm 15\%</math>                      Peg to EUR with band <math>\pm 15\%</math>                      Free floating  <i>Inflation targeting since 08/01</i></p>	<p>01/93 – 12/96                      01/97 – 12/99                      01/00 – 04/01                      05/01 – 09/01                      10/01 – 02/08                      02/08 –</p>
<p><b>Poland</b>                      Crawling peg to currency basket (45% USD, 35% DEM, 10% DEM, 5% FRF, 5% CHF) with band <math>\pm 1\%</math>                      Crawling peg to currency basket (45% USD, 35% DEM, 10% DEM, 5% FRF, 5% CHF) with band <math>\pm 7\%</math>                      Crawling peg to currency basket (45% USD, 35% DEM, 10% DEM, 5% FRF, 5% CHF) with band <math>\pm 10\%</math>                      Crawling peg to currency basket (55% EUR, 45% USD) with band <math>\pm 15\%</math>                      Free floating  <i>Inflation targeting since 01/99</i></p>	<p>01/93 – 05/95                      05/95 – 02/98                      02/98 – 12/98                      01/99 – 04/00                      04/00 –</p>
<p><b>Romania</b>                      Tightly managed floating with USD as reference currency                      Tightly managed floating with reference currency basket (60% EUR, 40% USD)                      Tightly managed floating with reference currency basket (75% EUR, 25% USD)                      Tightly managed floating with EUR as reference currency                      Free floating  <i>Inflation targeting since 08/05</i></p>	<p>01/93 – 12/01                      01/02 – 12/03                      01/04 – 12/04                      01/05 – 08/05                      08/05 –</p>

<b>Slovakia</b>	
Peg to currency basket (60% DEM, 40% USD) with band $\pm 1.5\%$	01/93 – 12/96
Peg to currency basket (60% DEM, 40% USD) with band $\pm 7\%$	01/97 – 09/98
Managed floating	10/98 – 11/05
ERM II	11/05 –
<i>Inflation targeting since 01/05</i>	

Source: International Monetary Fund, Frömmel and Schobert (2006), Barisitz (2007)

### Theoretical concept and literature review

This study is based on the following assumption. If the exchange rate developments of a euro-candidate currency and EUR are highly synchronized the euro-candidate country is ready to join the Eurozone. We chose USD as the common reference currency because the United States are likely to stay outside the Eurozone and USD plays a dominant role in financial markets, official reserves holdings as well as international trade.

The level of convergence of the exchange rate development is estimated with correlation analysis employing both simple and rolling approaches. The rolling correlation is used to overcome the time invariance of the simple correlation coefficient. In order to obtain a rolling correlation we construct a 256-trading-day (one calendar year) window moving correlation coefficient. The correlation analysis is applied on two kinds of time series – exchange rate daily returns and estimated conditional volatility.

The daily returns are calculated in a standardized way:

$$Y_t^j = [\log(S_t^j) - \log(S_{t-1}^j)] \cdot 100 \quad (1)$$

where  $Y^j$  is the exchange rate daily return of the of currency  $j$ ,  $S^j$  is the exchange rate of currency  $j$  at time  $t$  or  $t-1$ , respectively.

The conditional variance time series are generated by the estimation of GARCH (1,1) model. Subsequently, their daily changes are used in the correlation analysis of the exchange rate volatility. We apply the following GARCH model specification:

$$\Delta S_{jt}^D = \mu_j + \xi_{jt}, \quad (2)$$

$$\sigma_{jt}^2 = \gamma_{j1} + \gamma_{j2} \xi_{jt-1}^2 + \gamma_{j3} \sigma_{jt-1}^2 + \omega_{jt} \quad (3)$$

where  $S_{jt}^D$  denotes the log exchange rate of the currency  $j$  vis-à-vis the Dollar in the time  $t$ . Besides the constant term, the mean equation (2) does not include any



other explanatory variable. The constant term  $\mu_j$  shows the average rate of depreciation or appreciation. The error term,  $\xi_{jt}$ , of the mean equation (2) is assumed to have a time varying conditional variance,  $\sigma^2$ , specified by equation (3). Equation (3) comprises the ARCH term,  $\xi_{jt-1}$ , that reflects the impacts of news from previous periods that affect exchange rate volatility, and the GARCH term,  $\sigma_{jt-1}^2$ , that measures the impact of the forecast variance from previous periods on volatility.

The long-term similarity of the exchange rate development of two currencies vis-à-vis the reference currency may reflect the fact that both currencies are affected by similar factors. Similarly, convergence of the exchange volatility implies that shocks on exchange rates are accommodated symmetrically, i.e. in a similar direction and intensity. Hence, a concurrent achievement of high correlation in exchange rate development and exchange rate volatility may be interpreted as a sign of sufficient symmetry and readiness of the candidate country for joining the Eurozone and adoption of the single currency.

This approach to investigation of the exchange rate convergence has not been applied extensively so far in the literature. Komárková and Komárek (2007) used the static and time-varying correlation analysis on weekly nominal exchange rate data of four central European countries (Czech Republic, Hungary, Poland, Slovakia) over the period 1995 – 2Q 2006. They came to the conclusion that CZK is the currency most synchronized with EUR/USD currency pair. On the other hand, PLN reported the lowest correlation coefficients over the whole period of estimation. The authors also point out that convergence of the exchange rate development has been increasing since the countries analyzed joined the EU in May 2004. Kang et al. (2002) followed the same approach in their analysis; however, they focused on Korean and Japanese exchange rates.

Since the traditional correlation analysis assumes linearity between two variables some researchers argue that it is not the most accurate technique for estimation of the exchange rate convergence. Thus, some alternative procedures have been introduced and applied in the literature. For instance, Arguilar and Hördahl (1998) propose construction of a time-varying correlation coefficient based on estimation of a bivariate GARCH model. The authors investigate this way a likelihood of 11 Eurozone candidate countries to join the Eurozone from the start.

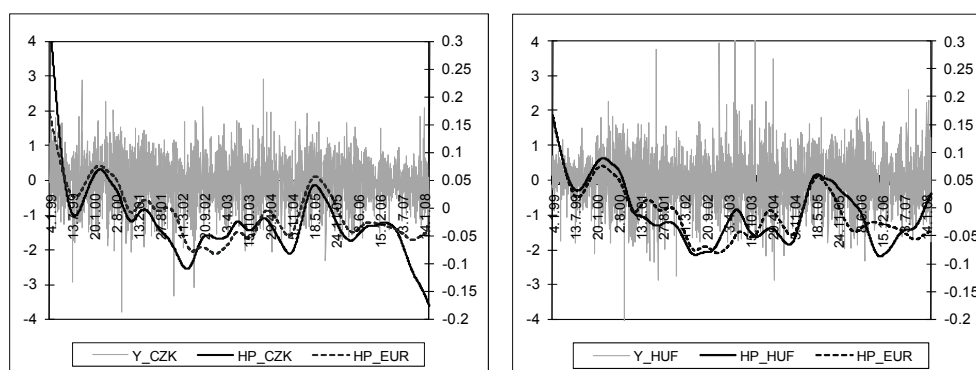
Babetskaia-Kukharchuk et al. (2008) use a bivariate version of the Baba-Engle-Kraf-Kroner GARCH model to calculate dynamic correlation coefficients of four central European currencies (CZK, HUF, PLN, SKK) with EUR. Employing daily nominal exchange rates from January 1994 to October 2005 they find evidence of convergence in exchange rate volatilities. The highest correlation coefficients were obtained for SKK, followed, with a marginal gap, by CZK and HUF. The convergence of PLN remained slow over the entire period analyzed.

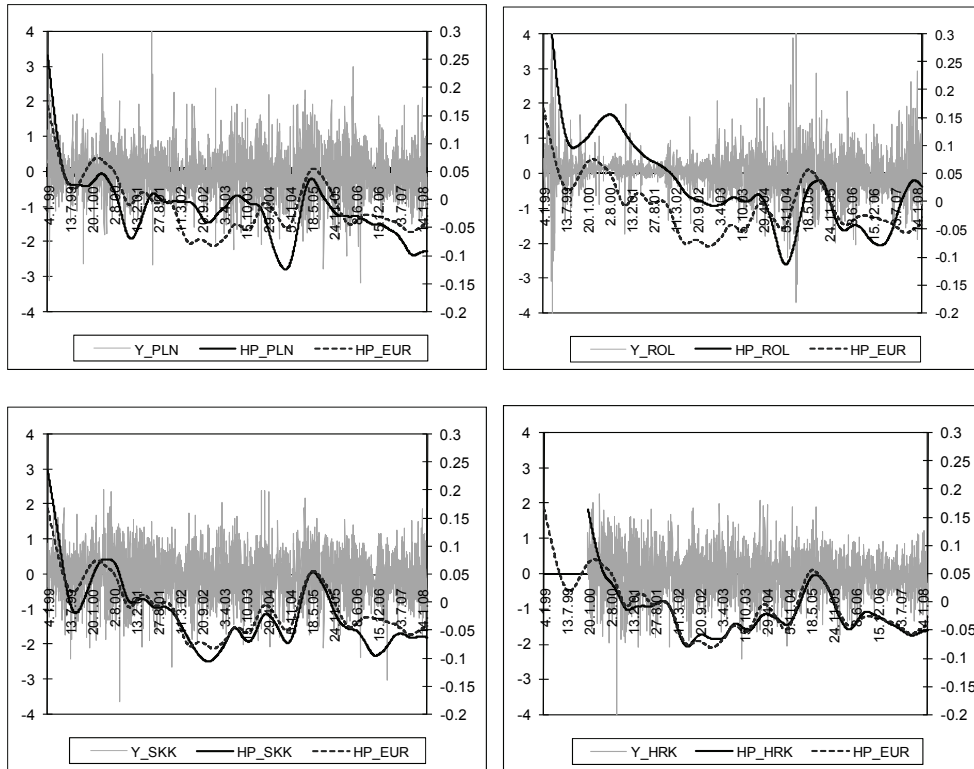
Some studies such as Aguilar and Hördahl (1998), Castrén and Mazzota (2005) or Nikkinen et al. (2006) use data on OTC currency option prices to obtain implied exchange rate volatility and calculate implied correlation coefficients.

### Empirical results

Before we proceed with presentation of the correlation analysis results, it is worthwhile to clarify the interpretation of the results. The correlation coefficient indicates strength and direction of a linear relationship between two variables and may gain values from minus one to one. The correlation is 1 in the case of an increasing linear relationship, -1 in the case of a decreasing linear relationship, and some value in between in all other cases implying the degree of the relationship. The closer the coefficient is to either of the extremes, the stronger the correlation between the variables.

From the NMS and EU candidate countries' point of view, it is desirable to have the development and volatility of the national currency perfectly correlated with EUR. Therefore, we interpret a highly positive correlation coefficient as signal of readiness for the euro adoption. Similarly, the increasing coefficient documents a greater likelihood of the Eurozone membership. However, it must be stated that convergence of the exchange rate development and volatility is not the only indicator that shall be used in making the decision on joining the Eurozone. See Angeloni et al. (2007) or Darvas and Szapáry (2008) for discussion on a variety of other suitable convergence indicators.





**Figure 2 Daily returns of exchange rates vis-à-vis USD**

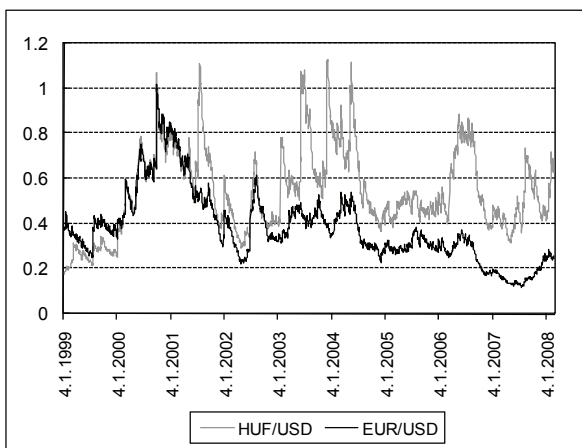
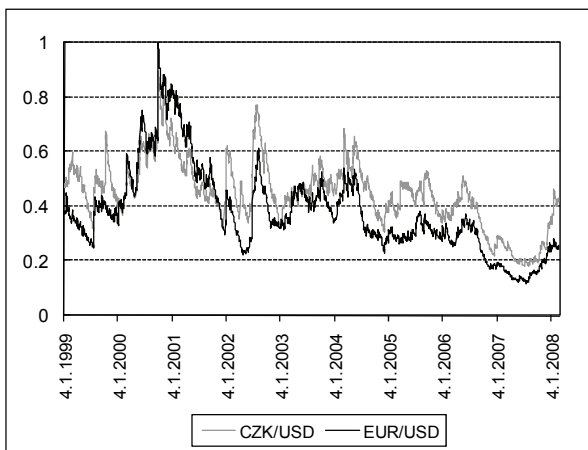
Source: Author's calculation

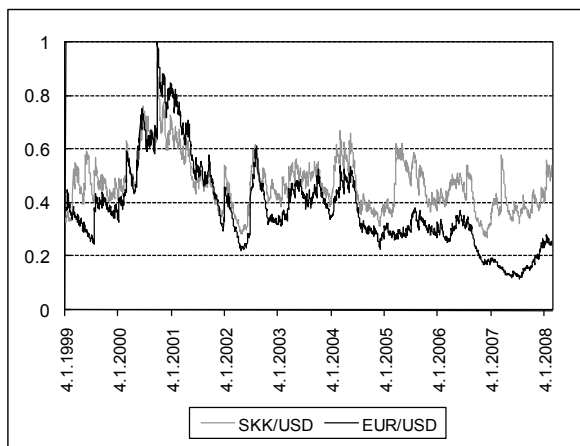
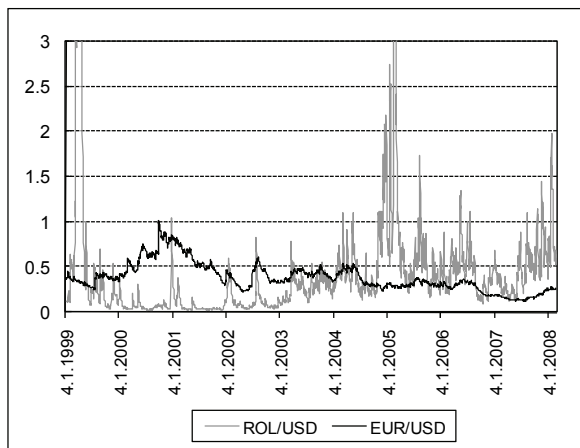
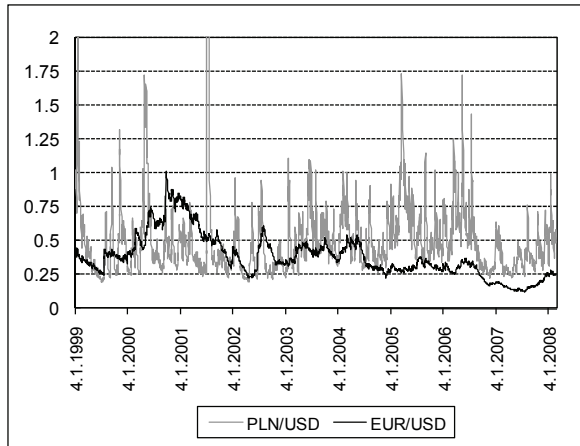
Note: HP indicates Hodrick-Prescott filter, HP series on the right axis

The first part of the correlation analysis is focused on convergence of the exchange rate development. Therefore, we calculated daily returns according to equation (1) for all exchange rate time series. We use exchange rates in direct quotes, i.e. number of domestic currency's units for one USD. In order to compare a trend development of the daily returns of the euro-candidate currencies and the euro we applied Hodrick-Prescott (HP) filter. Unfiltered as well HP filtered time series are graphically presented in Figure 2.

Even this simple graphical analysis indicates that development of some euro-candidate currencies is not synchronized with EUR over certain periods. Above all, we can mention the following currencies and episodes: CZK in 2002 and 2007-2008, HUF in 2003 and 2006, PLN in 2001-2002, ROL in 2007-2008 or SKK in 2006-2007. It clearly evident that, due to exchange rate regime applied, the exchange rate development of HRK is the most harmonized with the development

of EUR. As far as the daily returns' volatility is concerned, none of the currencies analyzed shows extraordinary figures.







**Figure 3 Conditional volatility estimated by GARCH model**

*Source: Author's calculation*

The second type of time series we used in the correlation analysis is conditional volatility generated by GARCH models estimation. Volatility of all exchange rates is depicted in Figure 3. For better comparison, volatility of each of the NMS national currencies is presented along with volatility of EUR/USD pair.

In general, the volatility of EUR/USD exchange rate is lower than the volatility of the euro-candidate currencies' exchange rates over the whole period of nine years and two months. The only exemption is 06/2000 – 06/2001, i.e. a turbulent period when waves of depreciation of EUR (euro-candidate currencies) against USD were often followed by an appreciation and vice versa. However, substantial differences in volatility can also be found among euro-candidate currencies. For instance, volatility of PLN exchange rate was usually twice as high as volatility of CZK or SKK. The volatility of ROL during the second half of the period analyzed even exceeded the PLN level.

Similarly with daily returns, HRK is the currency most harmonized with EUR. Volatilities of both currencies' exchange rates against USD are almost identical. One can reveal a high degree of convergence in the case of CZK and SKK. Volatility of HUF/USD exchange rate diverged from the EUR/USD development path in the second half of the period analyzed. However, the most remarkable differences in magnitude and fluctuations of volatility can be observed on PLN and ROL.

We start correlation analysis with the computation of a set of regular static correlation coefficients covering sub-periods of one year (the most recent sub-period is extended by two months to February 2008) as well as the entire period. All coefficients obtained are summarized in Table 2

**Correlation analysis of national currencies' exchange rates with EUR/USD**

Table 2

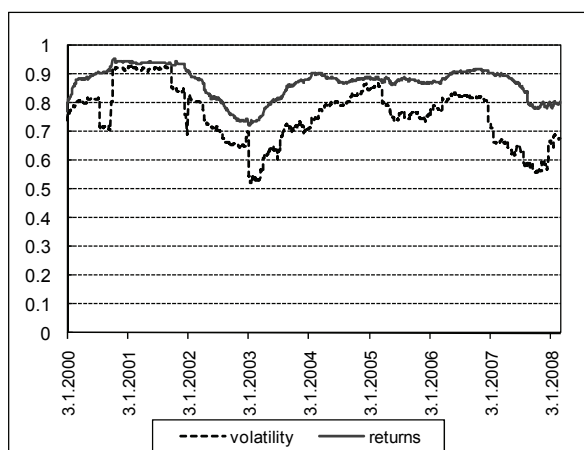
	1999		2000		2001		2002		2003	
	<i>returns</i>	<i>volatil.</i>	<i>returns</i>	<i>volatil.</i>	<i>returns</i>	<i>volatil.</i>	<i>returns</i>	<i>volatil.</i>	<i>returns</i>	<i>volatil.</i>
CZK	0.7705	0.7416	0.9445	0.9135	0.9085	0.6927	0.7453	0.7020	0.8817	0.7104
HUF	0.8375	0.7773	0.9933	0.9829	0.7904	0.5353	0.8645	0.8041	0.7005	0.3195
PLN	0.3465	0.4083	0.5123	0.1880	0.3397	0.0626	0.3993	0.1668	0.6436	0.3771
ROL	0.0453	0.0433	0.0554	0.0205	0.1247	0.0326	0.2000	0.0971	0.8174	0.6556
SKK	0.8458	0.7367	0.9413	0.9190	0.9511	0.8623	0.8722	0.7794	0.9275	0.8960
HRK	NA	NA	0.9926	0.9894	0.9054	0.8280	0.9611	0.9273	0.9455	0.9119
	2004		2005		2006		2007 – 02/2008		1999 – 02/2008	
	<i>returns</i>	<i>volatil.</i>	<i>returns</i>	<i>volatil.</i>	<i>returns</i>	<i>volatil.</i>	<i>returns</i>	<i>volatil.</i>	<i>returns</i>	<i>volatil.</i>
CZK	0.8864	0.8483	0.8710	0.7594	0.9037	0.7341	0.8063	0.6774	0.8626	0.7606
HUF	0.8495	0.7694	0.8631	0.7612	0.6920	0.5151	0.7511	0.5577	0.8068	0.6425
PLN	0.8049	0.6212	0.6975	0.6166	0.7435	0.5094	0.8325	0.6464	0.5680	0.3870
ROL	0.7394	0.6805	0.5854	0.5424	0.8257	0.6793	0.6392	0.4840	0.3840	0.3196
SKK	0.9676	0.9339	0.8424	0.6680	0.8768	0.7442	0.7912	0.4854	0.8944	0.7783
HRK	0.9221	0.8643	0.9537	0.9051	0.9691	0.9654	0.9681	0.9322	0.9528	0.9227

Source: Author's calculation

As Table 2 shows, correlation coefficients calculated of daily returns time series are higher than volatility-based coefficients. This is the case for all currencies and years. Even very strong development correlation (above 0.85) goes frequently hand in hand with substantially lower volatility correlation (e.g. CZK in 2006, SKK in 2005 and 2006 or PLN in 2007) in the recent years. This kind of disharmony may be explained by the fact that although the mentioned euro-candidate currencies and euro are influenced by similar factors (high development correlation) the final effect is not always of similar direction and intensity. One can also reveal that each currency analyzed tends to have its own correlation development pattern. While there are currencies with a remarkable growth of correlation coefficient over the estimated period (ROL, PLN), other currencies experienced a drop in correlation (HUF, SKK) or stagnation with only marginal changes in both directions (HRK). Hence, the standings of the most correlated currencies in the most recent sub-period (2007 – 02/2008) is as follows: HRK, PLN, CZK, SKK, HUF, ROL (in terms of daily returns) and HRK, CZK, PLN, HUF, SKK, ROL (in terms of volatility).

Despite fundamental differences we may underline some development episodes that were shared in common by all currencies. The correlation of volatility decreased on all currencies in 2001. It can be attributed to the effect of terrorist

attacks on financial markets and persisting uncertainty after that. By contrast, 2000 was the year when correlation of development increased on all currencies. As it is evident from Figure 1 and Figure 3, 2000 can be characterized as the year of a considerable USD appreciation against all other currencies and the year of increasing exchange rate volatility. Moreover, it is worthwhile to point out one more interesting episode that occurred in 2004 when ten NMS joined the EU. The correlation between all NMS currencies analyzed and the euro increased remarkably that year as compared with the 2003 figures. It is interesting that neither ROL nor HRK shared this development trend. Correlation coefficients from the most recent sub-period do not support the hypothesis of increasing exchange rate convergence between euro-candidate countries and the euro. Correlation of most of currencies shrank in 2007-2008 (except for HUF and PLN) to levels that cannot be considered as a zone of sufficient convergence.

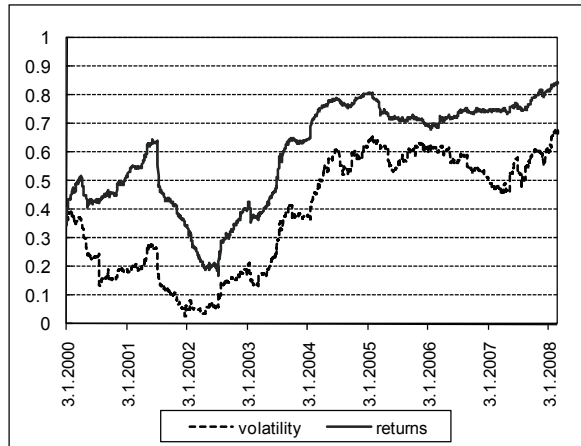


CZK/EUR – USD/EUR

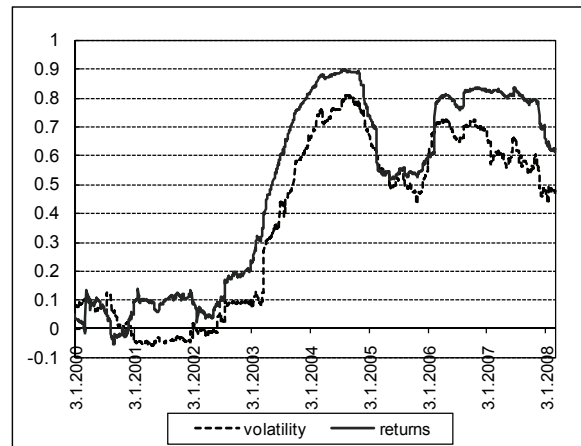


HUF/EUR – USD/EUR

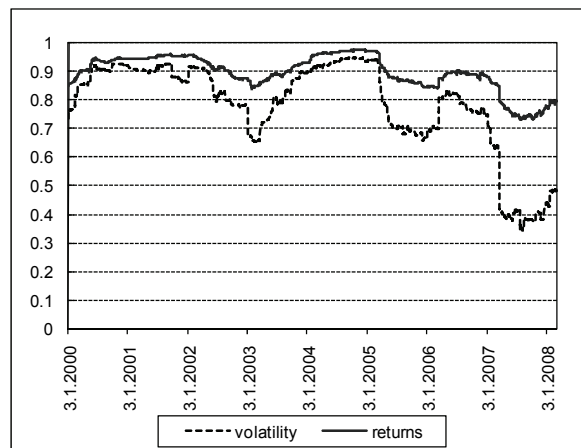




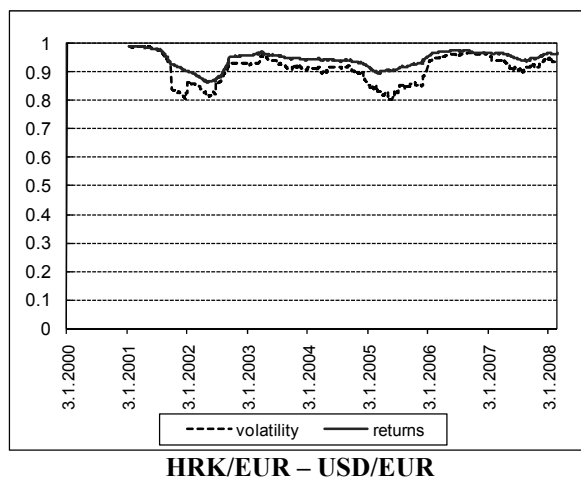
**PLN/EUR – USD/EUR**



**ROL/EUR – USD/EUR**



**SKK/EUR – USD/EUR**



HRK/EUR – USD/EUR

Figure 4 Rolling correlation coefficients

Source: Author's calculation

The traditional correlation analysis suffers from inherent lack of dynamics and lack of continuity. Therefore, in order to investigate dynamics of the correlation over time, we calculated rolling correlation coefficients. The length of the rolling window is one year. Thus, each rolling coefficient is based on data from the particular day of observation and 255 preceding trading days. Development of this consecutive measure of exchange rate convergence is graphically presented in Figure 4.

The results suggest that correlation of daily returns and correlation of volatility experienced very similar development as the increase (decrease) of the former is usually accompanied by a change of the latter in the same direction. However, the daily returns coefficients of all currencies exceeded the coefficient reporting the exchange rate volatility convergence. The gap between the two correlation coefficients was not constant but varied over the period of estimation. Occurrences of insignificant differences (e.g. HUF and SKK in 2000, CZK in 2001) were followed by circumstances when the daily returns coefficient was twice as high as the volatility coefficient (e.g. HUF in 2003 and first half of 2007, SKK in 2007-2008).

Such a disharmony emerged from substantial fluctuations in development of the volatility correlation coefficients. Almost all drops and increases in correlation were more rapid and intensive in the case of volatility correlation. The only exception was PLN whose volatility correlation with EUR was nearly as smooth as the daily returns correlation. PLN is the currency of the largest economy among NMS. Therefore, shocks and other impulses may be absorbed into exchange rate

development in a more delicate way as compared with other currencies from the region.

The results also provide evidence how the exchange rate regime applied may affect exchange rate convergence. Croatia was using very tightly managed floating of HRK with EUR as the reference currency over the whole period. Subsequently, the correlation of exchange rate development never decreased below 0.85 (0.93 in two last years) and the correlation of volatility never dropped under 0.8 (0.9 in two last years). Therefore, we can consider exchange rate convergence of HRK with EUR as almost absolute. On the other hand, the exchange rate arrangement used in Romania in 1999-2002 contributed crucially to the correlation oscillating around zero level and documenting virtually no convergence.

As far as the level of achieved convergence is considered, we can distinguish several sub-periods characterized by different levels of correlation as well as different standings of the most converged currencies. For instance, CZK, HUF and SKK recorded very high correlation coefficients of daily returns in 2000 and the first half of 2001. Most likely, such a development benefited from finalization of the treaties of EU accession. None of NMS negotiated the opt-out clause and thus, the euro adoption in those countries has been set as an unavoidable political and economic goal for the future.

The correlation of HUF began to fall first in July 2001 followed by CZK and SKK in December 2001. In July 2001, SKK became the currency most correlated with EUR and kept this position until May 2005. Development of the SKK correlation coefficient was almost perfectly paired with CZK as the gap remained very stable at 0.05. The coefficients of CZK, HUF and SKK converged to level 0.87 and persisted practically unchanged for next 10 months. After very heterogeneous development in the last year we ended up (besides HRK) with PLN as the most converged currency (correlation coefficient on 29 February 2008 was 0.8450) followed by CZK (0.8059), SKK (0.7937), HUF (0.7629) and ROL (0.6142). The leading position of PLN documents a great progress in convergence that has been achieved since PLN was the least converged NMS currency until September 2006. The worst result was recorded in July 2002 when the correlation coefficient was only 0.1661.

The correlation of exchange rate volatility went through a similar development, however the coefficients gained lower values and differences among currencies were more noticeable. At the end of the period analyzed (neglecting HRK with correlation coefficient 0.9364), CZK and PLN turned out to be the most synchronized currencies in terms of the exchange rate volatility. The respective coefficients were 0.6778 and 0.6718. The remaining standings were as follows: HUF (0.5793), SKK (0.4838) and ROL (0.4736). We believe that a long-persisting correlation above 0.85 may serve as an appropriate indicator of sufficient exchange rate convergence. However, as the results presented suggest, none of the NMS

currencies achieved such a level of convergence in the most recent period of time. For the worse, the analysis revealed that almost all currencies experienced a decline of convergence over the last year. This kind of development is not favorable mainly for Slovakia as SKK is supposed to be replaced by EUR on 1 January 2009.

The next issue that requires an in-depth analysis is the relationship between exchange convergence and process of the European economic and monetary integration. The accession treaties that were discussed above resulted in enlargement of the EU on 1 May 2004 that comprised 10 NMS including Czech Republic, Hungary, Poland and Slovakia. We notice a clear trend of increasing convergence from March 2003 when all negotiations about conditions of entry had been concluded and all NMS were finalizing preparations for the EU membership. The trend of growing convergence continued after the day of enlargement and principally CZK and HUF recorded significant gains in volatility convergence. A wave of rapid appreciation in the second half of 2004 prevented PLN from more intensive volatility convergence. On the other hand, HRK and ROL, currencies that did not participate in the EU enlargement in 2004, experienced a substantial drop of the correlation over the immediate post-enlargement period. An extensive increase of ROL convergence occurred approximately one year before admission of Romania to the EU. However, the day of entry was followed by a steady decline of both types of the correlation.

We also can investigate impacts of the SKK entry into ERM II and revaluation of its central parity on the convergence. Both events took place unexpectedly and surprised participants in the foreign exchange market. SKK entered into ERM II on 25 November 2005 and one can identify only mediocre instant impact. However, as the post-entry period gains larger share in the one-year rolling correlation window there is evidence of increasing convergence. Hence, it can be deduced that the entry into ERM II was perceived by financial markets as a firm commitment of the Slovak government to fulfill all convergence criteria and adopt EUR as soon as possible. On the contrary, several months later SKK speeded up its appreciation against EUR as well as USD and the actual market exchange rate departed remarkably from the central parity. This kind of development was reflected in a decrease of correlation. The official reaction to the excessive appreciation came out on 19 March 2007 in the form of a revaluation of the ERM II central parity. Consequently, a significant drop in convergence occurred immediately. This shift of the central parity brought along uncertainty to the foreign exchange market since it might cause some troubles with fulfillment of the exchange rate stability convergence criterion.

## Conclusion

In this paper, we analyzed exchange rate convergence of the euro-candidate currencies with EUR against USD. We constructed static as well as rolling correlation coefficients which provide evidence of achieved level of convergence in terms of exchange rate development and volatility. The higher the correlation is between national euro-candidate currency and EUR, the higher the exchange rate convergence. Apparently, a long-lasting high degree of convergence with a clearly stable or increasing trend is the most plausible scenario.

With empirical results obtained, we may conclude that the convergence of exchange rate development surpassed the convergence of volatility on all currencies and over the entire period of estimation. It is also evident that a tightly managed floating with EUR as the reference currency leads automatically to a more stable and robust correlation. We did not find any progress in convergence of the NMS currencies since their entry to the EU. The most remarkable upturns of convergence were recorded during the pre-EU-entry period. On the contrary, after the EU entry convergence of all NMS currencies, except for PLN, decreased. We witnessed a more significant decline in the case of volatility convergence.

Although some of the recent values of correlation coefficients are solid and demonstrate a fair synchronization, none of them (besides HRK) are so high as to allow us to consider the level of convergence as sufficient. The underlying shocks are still not fully symmetric which results in a lower convergence of the exchange rate volatility. This conclusion supports strategies of the Czech Republic, Hungary and Poland to postpone the day of entry into ERM II. The analysis findings also provide evidence that the euro adoption in Slovakia, expected on 1 January 2009, is seen as premature from the exchange rate convergence point of view.

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