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DETERMINANTS OF EXCHANGE RATE VOLATILITY: THE CASE OF THE NEW EU MEMBERS

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Determinants of Exchange Rate Volatility: The Case of the New EU Members*

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Abstract

Exchange rate stability is not only a criterion for joining the EMU but also a fundamental property of stable economic development. At the present time, new members of the EU are trying to achieve this stability. However, there are several factors that could slow down or interrupt these countries' EMU integration process. In order to try to prevent possible failure, this paper analyzes key factors contributing to euro exchange rate volatility in the new EU members – the openness of an economy, the "news" factor, and the exchange rate regime. The TARCH model is employed to model the volatility of exchange rates. The results suggest that the openness has a negative effect on exchange rate volatility. Furthermore, there is a significant effect of "news" on exchange rate volatility. The extent of both these effects varies substantially across countries.

Keywords: exchange rate volatility, TARCH, openness, news, regime, EMU integration
JEL classification: C32, C82, F02, F31

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1 Introduction

The goal of this paper is to analyze the sources of euro exchange rate volatility for six central and eastern European countries (CEEC-6) that accessed the European Union (EU) in May 2004[1]. As possible sources, I am interested in the openness of an economy, the "news" factor, and the exchange rate regime due to their undisputed contribution to exchange rate movements. This kind of study is crucial for the process of Economic and Monetary Union (EMU) integration of which all of these six new member countries are a part. Since these countries are trying to fulfill exacting criteria imposed by the EU, including stable exchange rates, it is necessary and beneficial to know the source of their possible failure. However, it is not only self-serving to know this: In accordance with other studies, this project might actually prevent this failure by serving as a guide for governments. To my knowledge, this project is the first study investigating the sources of exchange rate volatility in the CEEC-6 group.

One of the reasons for establishing the EMU was to promote exchange rate stability among member countries and to encourage trade inside the EU. Otherwise, exchange rate instability could have a negative impact on investment and trade. In the case of sudden movements of an exchange rate, domestic risk-averse companies could turn their focus on the domestic market rather than on the foreign one because the amount of their revenue would become unclear (Dell'Ariccia 1999). In fact, this exactly opposes the aim of the EU.

As a result of EU enlargement, ten new countries joined the EU in May 2004. The process of their accession further continues as they prepare to join the EMU probably around 2010. By that time, these countries have to fulfill the Maastricht

[1]These are the Czech Republic, Hungary, Latvia, Poland, Slovakia, and Slovenia. I do not include Malta and Cyprus here since these two countries are not in the process of transition and they are considered to be functioning market economies. Moreover, Estonian kroon and Lithuanian litas are firmly linked to the euro, and therefore, Estonia and Lithuania are not included in this research either.

criteria[2]. This research focuses on factors that can jeopardize the process of fulfilling the second of these criteria – the Exchange Rate Mechanism (ERM) criterion which defines the exchange rate of the participating currency against the euro. The currency can fluctuate around the central rate by ±15%.

The paper is structured as follows. The second section deals with previous studies relevant for this research. The methodology is explained in the third section. The fourth section comprises data description and the fifth one presents the empirical results. The last section concludes.

2 Literature Review

There is a variety of factors contributing to the fluctuation of an exchange rate, e.g. the openness of an economy, the domestic and foreign money supplies, the exchange rate regime, interest rates, central bank independence, levels of output, income, inflation, and unpredictable circumstances. The degree of the impact of each of these factors varies and depends on a particular country's economic condition. However, the countries that are in the process of transition (CEEC-6 group) are more vulnerable to being affected by these factors. Although this paper analyzes just a few of these factors, according to the empirical literature mentioned below, they should be the ones with the biggest impact. In the following section, I explain my incentives for choosing particular factors as well as their validity.

[2]These criteria require that:

- the national central bank of the country should be independent;
- the country's currency should have participated without stress in the Exchange Rate Mechanism for at least two years;
- the country's inflation rate should have been below a reference value given by a range of $1\frac{1}{2}$ percentage points above that of the best three inflation performers;
- the country's long-term interest rate should have been within two percentage points of that of the three best inflation performers; and
- the ratio of the budget deficit to gross domestic product (GDP) should not exceed 3%, and its debt-to-GDP ratio should not exceed 60%.

2.1 Openness of Economy

As was discussed above, one of the reasons for establishing the EMU was to promote a greater openness of economies and higher exchange rate stability among EU countries. However, you cannot achieve one without achieving the other. Thus, it is likely that there is a close link between these two factors. One of the studies dealing with these factors was elaborated by Hau (2002). Particularly, the author analyzes the openness of an economy and its impact on real exchange rate movements. He claims that trade integration and real exchange rate volatility are structurally linked and there is a negative correlation between them. As support, he uses a small open economy model with a tradable and a non-tradable sector. The solution of this model indicates that more open economies have a more flexible aggregate price level. This flexibility reduces the effect of unanticipated money supply shocks. It further results in lower real exchange rate volatility for countries with a higher openness of the economy. According to Hau, this relationship is robust for the assumption of competitive as well as monopolistic markets for tradables. Moreover, Hau derives the same relationship under the assumption of an unanticipated labor supply shock. Hau further supports his claim by empirical research with a sample of 48 countries over a 19 year time period. As a proxy for openness he uses an import vs. GDP ratio. Real exchange rate volatility is measured as the standard deviation for the percentage changes of the effective real exchange rate over intervals of 36 months. Additionally, his cross-sectional regression allows also for a mixture of control variables[3]. Depending on a particular chosen sample and the control variables, the results state the impact of openness of an economy on exchange rate volatility to be statistically significant at least at the 5% significance level (in most cases even at the 1% significance level) and openness to explain up to 52% of

[3]Hau uses the following indicators as control variables: log per capita GDP, political stability, an oil exporting dummy, the exchange rate regime, central bank independence, and a core EMS dummy.

exchange rate variations. Similar results are obtained also at higher frequencies[4]. However, Hau's results do not say anything about particular countries because each country is represented only by arithmetic mean values over the whole period.

2.2 Unpredictable Circumstances

The next factor analyzed in this paper concerns unpredictable circumstance or news. This affects all real variables as well as asset yields. In stock markets simple information, often not even valid, might cause huge movements of stock prices. The behavior of exchange rates is very similar, and the consequences of events like government crises, market crises, industrial shocks and terrorist attacks are undisputed. The role of news as the predominant cause of exchange rate movements has been emphasized already in studies by Dornbusch (1978) and Frenkel (1981). The latter one, by Frenkel, studies volatility of the US exchange rates between GBP, FFR and DEM[5]. The first part of his paper concerns exchange rate movements and their predictability where he claims that the predicted changes in exchange rates capture only a small fraction of actual changes. Therefore, since most changes in exchange rates are unanticipated, most of them happen due to some new information. Frenkel supports this by an 8-year period of monthly data of the US/GBP; US/FFR; and US/DEM exchange rate movements. He further states that current spot prices convey all information and expectations about the future, and there is no better guess about the next period price than the current one. According to Frenkel's study, the correlation between the forward and spot exchange rate is more than 0.99, and the correlation between percentage changes in them is more than 0.96 for all three pairs of currencies. Nevertheless, the author does not provide a correlation coefficient between the forward and the next period spot exchange rate which might reveal even more the importance of the news effect.

[4] 1 month, 3 months, and 12 months

[5] GBP = Great Britain Pound, FFR = French Franc, DEM = Deutsche Mark

In the second part of his study, Frenkel, seeking a suitable instrumental variable for modeling news, discusses the relationship between exchange and interest rates. Although macroeconomic theory explains the negative impact of interest rates on exchange rates *via* capital/current accounts, he claims, based on empirical results from US data, that it does not hold in an inflationary environment, and the impact is actually positive[6]. Furthermore, in line with the rational expectations hypothesis indicating the predominant role of news in affecting real variables and Dornbusch (1978), who decomposes the news effect into "those which alter the expected future spot rate between the last period and the present, and those which lead to a reassessment of the 1-period interest rate differential,"[7] Frenkel proposes a model for estimating the effect of news on exchange rate variability:

$$\ln S_t = a + b \ln F_{t-1} + \alpha \left[(i - i^*)_t - E_{t-1}(i - i^*)_t \right] + \omega_t,$$

where S_t is spot rate, F_{t-1} is lagged forward exchange rate, i is interest rate in home currency, i^* is interest rate in foreign currency, and $E_{t-1}(.)$ represents the interest differential expected at time t based on information available at time $t-1$. The first two components on the right-hand side represent the expected exchange rate and the term in brackets represents news. According to Frenkel, applying this regression on all three pairs of currencies (separately) indicates a positive correlation between news and exchange rates, although this correlation differs significantly from zero only for US/GBP and US/FFR exchange rates. However, there is a weakness in these results. Frenkel uses $\ln S_t$ as a dependent variable but he does not consider that this time series is most likely non-stationary. He also does not take into account asymmetric effects of positive and negative news. Moreover,

[6]However, based on the empirical results from Frenkel's study, the macroeconomic theory holds in this case because the effect is negative for all three exchange rates, although it does not differ significantly from zero.

[7]Frenkel (1981), pp. 686.

monthly data, used by Frenkel, cannot capture the moment of surprise caused by some new information. Therefore, I expect to obtain better and more significant results using higher frequency data.

The effect of news is discussed also in a study by Galati and Ho (2003) who investigate to what extent daily movements in the euro/dollar exchange rate are driven by news. Finding again a statistically significant correlation between them, good news results in the appreciation of currency, and vice versa. For modeling news they use a similar approach to Frenkel – the difference between the actual and forecasted values – although they measure it on various macroeconomic indicators[8]. The exchange rate movements are captured by the differences in values of logarithm of the spot prices. Additionally, although Galati and Ho focus also on studying asymmetric behavior of an exchange rate with respect to good or bad news, they do not find any significant asymmetry. On the other hand, Engle and Ng (1993) claim the asymmetric effect of news on volatility and suggest various modifications of the ARCH model[9] for emulating exchange rate volatility. For example, the EGARCH model allows different impacts of good and bad news, as well as major and minor news. In the spirit of this asymmetry, Sanchez-Fung (2003) studies daily returns, volatility, and news in the foreign exchange market of the Dominican Republic concluding that impact on the volatility of exchange rate returns is higher for positive shocks (depreciations) than for negative ones (appreciations).

2.3 Exchange Rate Regime

The last but equally important factor is the exchange rate regime. It is a well known fact that nominal exchange rate variability is lower in the case of fixed exchange

[8]change in non-farm payrolls, the unemployment rate, the employment cost index, durable goods orders, NAPM manufacturing, NAPM non-manufacturing, advance retail sales, industrial production, the consumer price index, and the producer price index

[9]The autoregressive conditional heteroskedasticity model (ARCH) was introduced by Engle (1982). Later, this model was generalized (GARCH) by Bollerslev (1986).

rates than for floating ones. For my research, examples of countries that adopted a floating exchange rate are Slovakia, Poland, and the Czech Republic, while Slovenia, Hungary, and Latvia prefer variations of a pegged exchange rate. However, according to Reinhart and Rogoff (2002), it is necessary to be careful while modeling different exchange rate regimes and not to blindly follow official classification of these regimes. For this reason, they study dual and parallel exchange rate markets on a sample of 153 countries over a 55-year time period. Based on this, they claim that a majority of official pegs are actually floats, and vice versa. As a result, they provide a new system for classifying exchange rate regimes with the accent on real and proclaimed regimes. Nevertheless, in order to see the effects of government policies on exchange rate volatility, my research studies the impact of official exchange rate regimes only.

2.4 Volatility of Exchange Rate

There are further studies concerning exchange rate volatility, although mostly they investigate the impact of exchange rate volatility rather than sources of this volatility. However, besides other things (such as the subject of study), they differ in the way of modeling exchange rate volatility. According to this modeling, they can be divided into two groups – the ones that use various modifications of standard deviations and the ones that use modifications of the ARCH approach. Belke and Setzer (2003) belong to the former group. They study the impact of exchange rate volatility on the labor market. In their case, the exchange rate volatility is measured as the standard deviation of the 12 month-to-month changes in the logarithm of the spot rate. Dell'Ariccia (1999) studies the effect of exchange rate volatility on bilateral trade flows. He uses the standard deviation of the first difference of the logarithmic exchange rate as well, but he also employs also two other measures – the sum of the squares of the forward errors and the percentage difference between

the maximum and minimum nominal spot rate. Moreover, there are studies, such as Kenen and Rodrik (1986); Koray and Lastrapes (1989); and Chowdhury (1993) that model the exchange rate volatility as the moving sample standard deviation of the growth rate of the real exchange rate. On the other hand, Baum et al. (2004), analyzing the impact of exchange rate volatility on the volume of bilateral exports, and Choudhry (2005), investigating the influence of exchange rate volatility on real exports, apply the GARCH model for measuring volatility. Further modification of the ARCH approach can be found in Orlowski (2003) who studies the impact of monetary policy regimes on lowering inflation and the exchange rate risk premium in Hungary, Poland, and the Czech Republic. Here, for modeling exchange rate volatility he employs the TARCH model. Moreover, Valachy and Kocenda (2005), analyzing recent developments in exchange rate volatility in the Visegrad Group countries and selected EMU countries, suggest a usage of leverage GARCH model. As discussed above, this latter approach is plausible also for this research because its modification allows for an asymmetric, i.e. more realistic, impact of news on exchange rate volatility.

3 Methodology

The paper analyzes the volatility of the exchange rate between the euro and the domestic currency for six different countries. The crux of this project lies in properly choosing the way to model the analyzed factors, especially the openness of an economy and news and, more importantly, to approximate an otherwise unobservable volatility.

3.1 Factors

Starting with independent variables, for modeling the openness of an economy, I follow Hau (2002) and use a proxy defined as the ratio of quarterly imports and quarterly gross domestic product. However, in order to observe the effects of openness on exchange rate volatility caused only by structural changes in openness and not by business cycles noise, the Hodrick-Prescott filter[10] is applied on quarterly openness time series. Then, since I need a daily frequency time series, the resulting time series is extended such that it comprises only 4 different values for every year, and the same smooth ratio of quarterly imports and quarterly GDP is assigned to each day in a particular quarter.

Since it is difficult to observe and quantify unpredictable circumstances or news, I build on the specification proposed by Frenkel (1981), who, knowing the fact that asset markets clear fast and react immediately to news, creates a new variable

$$NEWS_t = (i - i^*)_t - E_{t-1}(i - i^*)_t, \tag{1}$$

where i is the interest rate in the home currency, i^* is the interest rate in the foreign currency, the first term in this difference denotes the innovation in the interest differential and the second one denotes the interest differential which was expected to prevail in period t based on the information available at $t-1$. Partially following Frenkel, the latter term is estimated from a regression of the interest differential on a constant, two-lagged values of the differential, and the logarithm of the lagged spot exchange rate. Frenkel is followed only *partially* because originally he suggests using the forward exchange rate instead of the spot exchange rate. However, since forward exchange rate markets are either not developed sufficiently or do not have a long history in the CEEC-6 group, the spot rate is used instead.

[10] This is a smoothing method used by macroeconomists to obtain a smooth estimate of the long-term trend component of a series, first used by Hodrick and Prescott (1997).

I justify this modification by Frenkel's own argumentation when he claims the correlation between the forward and spot exchange rate to be more than 0.99 in the case of his data. This is also the case for CEEC-6 where the correlation for available periods is more than 0.98 for every country.

For modelling different exchange rate regimes, I create a set of dummy variables for different regimes.

3.2 Measure of Volatility

As regards to the dependent variable, the volatility of exchange rates, I employ the threshold autoregressive conditional heteroskedasticity (TARCH) model. This model comprises a leverage term that allows for the asymmetric effects of good and bad news. The general $TARCH(p, q)$ model is specified as

$$r_t = a_0 + \sum_{i=1}^{P} a_i r_{t-i} + \sum_{i=0}^{Q} b_i \varepsilon_{t-i};\ \varepsilon_t \sim N\left(0, \sigma_t^2\right)$$
$$\sigma_t^2 = \omega + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2 + \sum_{i=1}^{q} \beta_i \sigma_{t-i}^2 + \xi d_{t-1} \varepsilon_{t-1}^2,$$

where variable r_t is the exchange rate change over two consecutive trading days, and σ_t^2 is the conditional variance that is a function of not only the previous realizations of ε_t, but also the previous conditional variances and the leverage term. The core of this leverage term is the dummy variable d_{t-1} that equals 1 in the case of a negative shock ($\varepsilon_{t-1} \leq 0$) and 0 in the case of a positive shock ($\varepsilon_{t-1} > 0$). Thus, the positive value of the coefficient ξ indicates an increased conditional variance by ε_{t-1}^2 in case of negative shocks or news that occur at time $t-1$, while the negative value of coefficient ξ indicates a decreased conditional variance. The additional restriction $\sum_{i=1}^{p} \alpha_i + \sum_{i=1}^{q} \beta_i < 1$ is a sufficient and necessary condition for stability of the conditional variance.

In order to get a properly specified model and correctly conditioned volatil-

ity, the most appropriate $ARMA(P,Q)$ model of the exchange rate volatility is estimated using the *Box-Jenkins* methodology[11]. Then the *Ljung-Box Q-test*[12] is applied to test squared residuals of the $ARMA(P,Q)$ model for the presence of conditional heteroskedasticity. The next step is to identify the orders of the $TARCH(p,q)$ process by experimenting with different orders p and q; estimating the whole $ARMA(P,Q) - TARCH(p,q)$ model; checking the significance of the estimated coefficients; and then diagnosing the standardized residuals. Once the presence of conditional heteroskedasticity is detected and the orders p and q of the TARCH process are chosen, the whole $ARMA(P,Q) - TARCH(p,q)$ model is estimated using the maximum likelihood estimation where the log-likelihood function has the form

$$L = -\frac{1}{2T}\sum_{t=1}^{T} \log \sigma_t^2 + \varepsilon_t^2/\sigma_t^2.$$

Finally, the standardized residuals are diagnosed by applying the *Ljung-Box Q-test* and the *LM test for the presence of an ARCH process*[13]. If the estimated model is a correct one, then these residuals should be white noise[14] and no further GARCH process should be present.

3.3 Model for Estimation of the Effects

Having estimated all the necessary variables, I perform the actual analysis of the impact of various factors by estimating the following model using OLS:

$$ERV_t = \alpha + \beta\left(\frac{Im_t}{GDP_t}\right) + \gamma_G G_t * NEWS_t + \gamma_B B_t * NEWS_t + \delta REGIME_t + \varepsilon_t, \quad (2)$$

[11] Box and Jenkins (1976)
[12] Ljung and Box (1978)
[13] Engle (1982)
[14] The latest literature suggests an even stronger condition. The standardized residuals should be tested for being *iid* because there might be hidden nonlinear patterns that are not detected if a white noise test is applied. For this purpose, one can apply the BDS test developed by Brock et al. (1987) or Kocenda's test, as its alternative, devised by Kocenda (2001). However, these two tests cannot be applied here, since they require the standardized residuals to have a normal distribution and the residuals estimated in this study do not have such a property.

where ERV_t denotes exchange rate volatility estimated in the previous TARCH model, G_t is a dummy variable that equals 1 in case of good news ($NEWS_t < 0$), B_t is a dummy variable that equals 1 in case of bad news ($NEWS_t > 0$) and $REGIME_t$ denotes a set of dummy variables for exchange rate regimes. This process is repeated for each of the six countries to see the different impacts on each particular currency. The interpretation of coefficient β is straightforward, a positive value of β results in increased volatility in the case of increased openness. Similarly, a positive value of coefficient δ results in increased volatility in the presence of a particular regime with respect to a base regime. However, the way of construction of variable $NEWS_t$ requires an opposite interpretation – if it is assumed that the interest rate in the foreign currency does not change due to news in home country and good news in home country leads to a decrease in the home currency interest rate, then good news results in negative value of variable $NEWS_t$. Thus, a negative value of coefficient γ results in increased volatility in the case of good news.

4 Data

All the data used in this project are collected with daily frequency during the period of January 1, 1999 – December 31, 2004 from several sources – IMF-IFS, Eurostat, national banks, and central statistical offices. Although there is another strand of literature that studies intraday volatility[15] using high frequency data with a several minute-long time interval (Cerny 2004), for the purpose of this project it is sufficient to use daily data. Using lower frequency data, e.g. monthly or quarterly, might result in the failure of this study because often it would not be able to capture any news effect on exchange rate movements.

The extent of openness differs substantially in the CEEC-6 group. While the value of Polish imports corresponds on average to 31% of GDP, in the case of Latvia

[15]Typically concerning stock market indices.

and Slovenia it is about 50%. The economies of the Czech Republic and Hungary are on average even more open (61%), but the biggest share of imports over GDP can be found in Slovakia (almost 70%). Figure 1 displays the openness path in each country before (dot line) and after (solid line) smoothing. All patterns exhibit an increasing trend except Hungary with its decreasing trend since the fourth quarter of 2001. Basic characteristics are summarized in Table 1.

Table 1: Openness after smoothing – data summary.

country	min	max	mean	st.dev.
Czech Republic	0.5706	0.6345	0.6153	0.0193
Hungary	0.5687	0.6241	0.6059	0.0155
Latvia	0.4685	0.5125	0.4829	0.0149
Poland	0.2882	0.3538	0.3112	0.0207
Slovakia	0.6093	0.7380	0.6903	0.0402
Slovenia	0.4886	0.5229	0.5060	0.0098

The factor of news is modeled from a particular country's interest rates (IBORs) with maturity 3 months[16]; the Central European Bank's interest rates (EURIBOR) with the same maturity; and the spot exchange rates against the euro. The overview of adopted exchange rate regimes in each country can be found in Table 2. Unfortunately, since Slovakia, Latvia, and the Czech Republic did not change their exchange rate regime during the whole time span, the factor of regime is not analyzed as a source of exchange rate volatility in their case. Finally, the basic characteristics of nominal exchange rates of each CEEC-6 country's currency vis-à-vis the euro are summarized in Table 3. Corresponding exchange rate changes are displayed in Figure 2. Looking at this figure, there is a general trend of lowering volatility at the end of the time span. Regarding the connection between volatility and real-life events, there is a tendency for increased volatility prior to presidential or parliamentary elections, although this is not always the case. In the case of Hungary,

[16]PRIBOR for the Czech Republic, BUBOR for Hungary, RIGIBOR for Latvia, WIBOR for Poland, and BRIBOR for Slovakia. In the case of Slovenia, interbank money market rates for deposits up to 30 days are used instead due to the lack of SITIBOR data.

there is a visible change in regime in May 2001 with much higher volatility afterwards. On the other hand, Slovenia has extremely low volatility which is the result of tight exchange rate regime during the whole time span.

Table 2: Exchange rate regimes – an overview.

country	variable	period	regime
Czech Rep.	–	27.5.1997– ...	managed floating
Hungary	REG1	1.1.1999–31.12.1999	crawling band around basket (±2.25%) (basket=USD 30%, EUR 70%)
	REG2	1.1.2000–3.5.2001	crawling band around EUR (±2.25%)
	REG3	4.5.2001–4.6.2003	crawling band around EUR (±15%) (central rate 276.10 HUF/EUR)
	base	4.6.2003– ...	crawling band around EUR (±15%) (central rate 282.36 HUF/EUR)
Latvia	–	09/1994– ...	peg to SDR
Poland	REG1	1.1.1999–23.3.1999	crawling band around basket (±12.5%) (basket=USD 45%, EUR 55%)
	REG2	24.3.1999–12.4.2000	crawling band around EUR (±15%)
	base	12.4.2000– ...	managed floating
Slovakia	–	1.10.1998– ...	managed floating
Slovenia	REG1	1.1.1999–27.6.2004	crawling band around EUR (±2%)
	base	27.6.2004– ...	ERM II

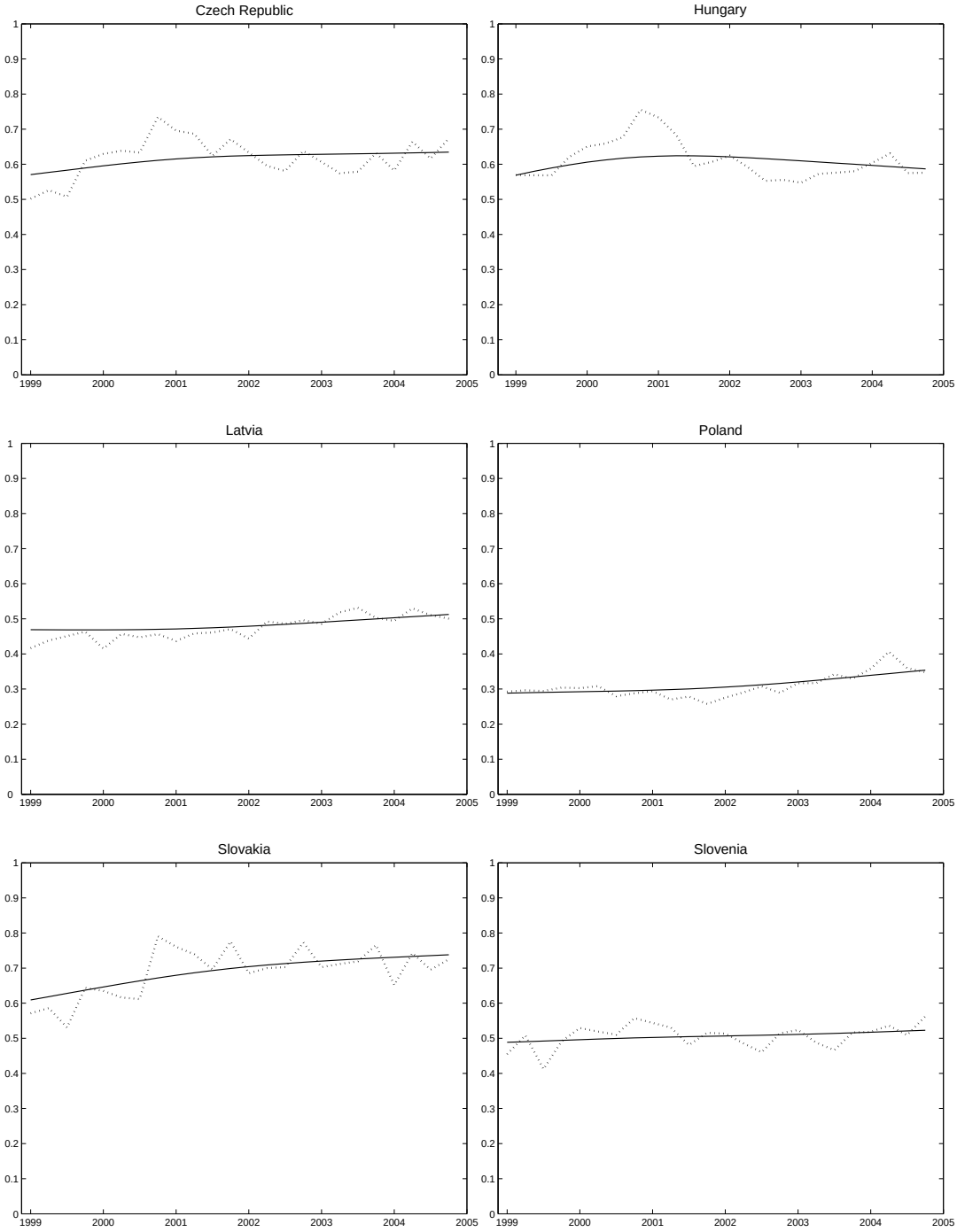
Note: SDR=USD,GBP,EUR, and YEN
Source: Reinhart and Rogoff (2002), Valachy and Kocenda (2005), national banks

Table 3: Nominal exchange rates vis-à-vis the EUR – data summary.

country	min	max	mean	st.dev.
Czech Republic	28.9590	38.5830	33.5196	2.2916
Hungary	234.7200	273.9200	252.9331	7.7495
Latvia	0.5191	0.6980	0.6055	0.0438
Poland	3.3433	4.9346	4.1169	0.3439
Slovakia	38.5450	47.4840	42.3693	1.5187
Slovenia	187.1333	240.0300	219.6494	15.6962

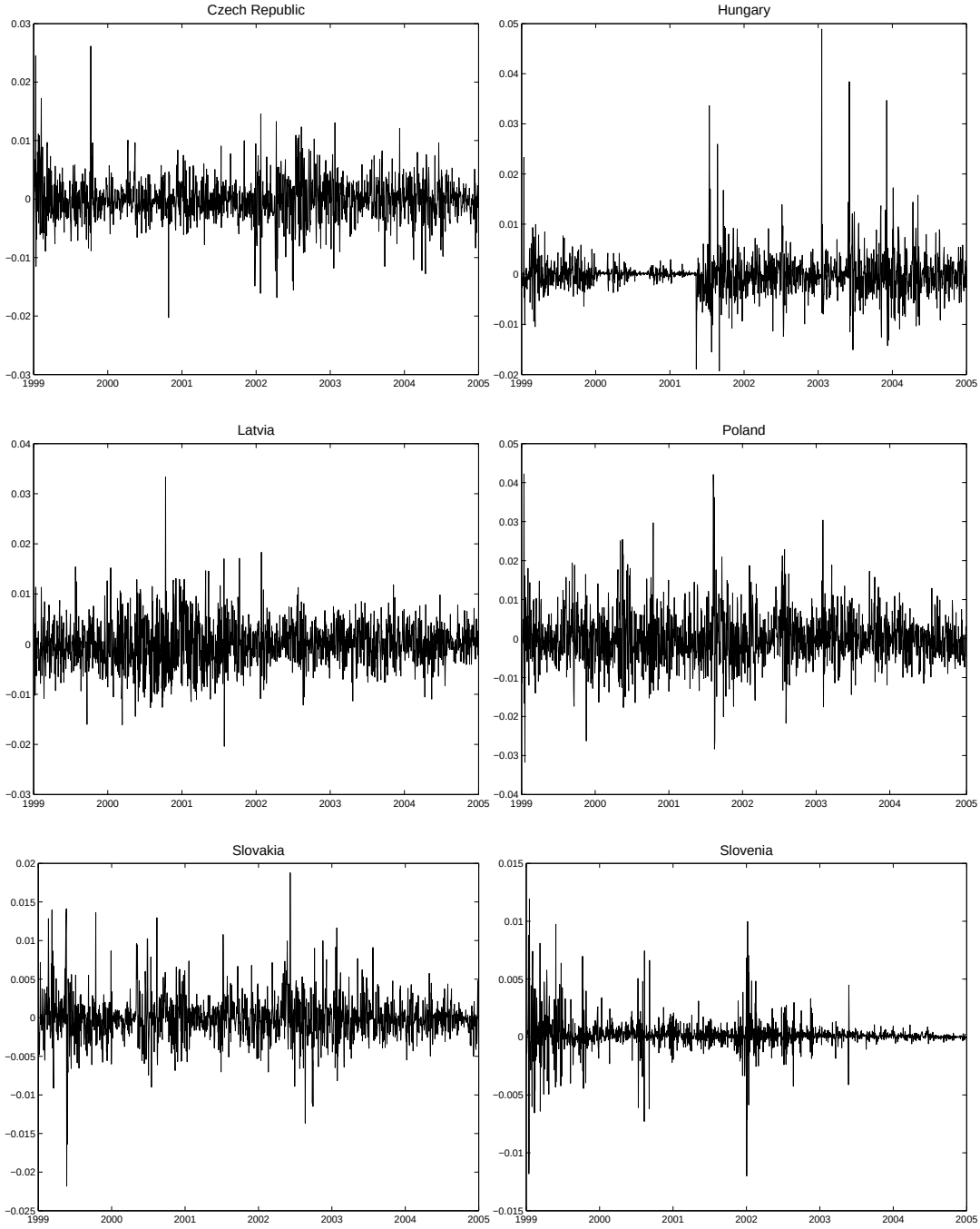
Source: author's calculations

Figure 1: Openness in the CEEC-6 group during 1999-2004.



Source: IMF-IFS, Eurostat, and author's calculations

Figure 2: Exchange rate changes in the CEEC-6 group.



5 Empirical Results

The first stage of analyzing the effects of determinants of exchange rate volatility consists of estimating the corresponding TARCH model for each currency. The results of these estimations are summarized in Table 4. Except Slovenia, the results suggest that in the CEEC-6 group the exchange rate volatility is statistically significantly asymmetrically affected by unpredictable circumstances. The sign of leverage term implies lower conditional variance in the case of a negative shock for Hungary, Poland, and Slovakia, while for Latvia and the Czech Republic it implies higher conditional variance. In the case of Slovenia, a simple ARCH model with variance as an ARCH-M term is estimated instead. For each country the sum of α's and β's in variance equation satisfies a stability condition, which implies that exchange rate changes converge to steady-state level, although this convergence is slow in the Czech Republic and Latvia with sums close to one. Additionally, the value of coefficient β in GARCH term close to one suggests that there is a high persistence of conditional variance in these two countries. Regarding asymmetric effects and variance persistency, these results are in accord with previous studies by Orlowski (2003) and Valachy and Kocenda (2005), although these studies do not deal with Latvia and Slovenia.

Once the correct ARCH model is specified, conditional variance from this model is calculated. Moreover, variable $NEWS$ is estimated from equation (1). Basic characteristics about variance and news are presented in Table 5 and 6 respectively. Estimated conditional variance is depicted in Figure 3.

Then, the final stage is to run a regression (2). This regression is run without $REGIME$ variable for the Czech Republic, Latvia, and Slovakia, since these countries did not change their exchange rate regime during the whole time span. I allow also for lags of variable $NEWS$ in this regression in order to capture delayed effects of news. The results of these estimations are summarized in Table 7. The negative

Table 4: TARCH model estimations.

	Czech Rep.	Hungary	Latvia	Poland	Slovakia	Slovenia
σ^2	–	–	–	–	–	55.8525^a
	–	–	–	–	–	(9.4673)
a_1	–	0.0857^b	–	–	0.0855^a	-0.2439^a
	–	(0.0424)	–	–	(0.0316)	(0.0604)
a_2	–	–	-0.0496^c	-0.0781^a	–	–
	–	–	(0.0267)	(0.0291)	–	–
a_5	-0.4526^a	-0.0766	–	–	–	–
	(0.1446)	(0.0472)	–	–	–	–
a_6	–	-0.0779^a	–	–	–	–
	–	(0.0287)	–	–	–	–
a_{10}	–	–	–	0.0846^a	–	–
	–	–	–	(0.0262)	–	–
a_{12}	–	–	0.0649^b	–	–	–
	–	–	(0.0256)	–	–	–
b_5	0.4768^a	–	–	–	–	–
	(0.1424)	–	–	–	–	–
ω	$2 \cdot 10^{-7}$	$9 \cdot 10^{-6a}$	$3 \cdot 10^{-7b}$	$2 \cdot 10^{-5a}$	$5 \cdot 10^{-6a}$	$5 \cdot 10^{-7}$
	$(1 \cdot 10^{-7})$	$(3 \cdot 10^{-6})$	$(1 \cdot 10^{-7})$	$(2 \cdot 10^{-6})$	$(7 \cdot 10^{-7})$	$(8 \cdot 10^{-6})$
α_1	0.1203^b	0.4318^a	0.0319^b	0.2000^a	0.2201^a	0.6542^a
	(0.0570)	(0.1667)	(0.0142)	(0.0502)	(0.0648)	(0.1544)
α_2	-0.0849	0.3263^b	–	0.1276^a	0.1208^b	0.2167^b
	(0.0520)	(0.1505)	–	(0.0467)	(0.0580)	(0.1053)
α_3	–	–	–	0.1753^a	0.0495	–
	–	–	–	(0.0491)	(0.0338)	–
α_4	–	–	–	0.0809^b	–	–
	–	–	–	(0.0373)	–	–
β_1	0.9114^a	–	0.9189^a	–	–	–
	(0.0216)	–	(0.0180)	–	–	–
ξ	0.0779^b	-0.3332^b	0.0702^b	-0.1995^a	-0.1347^c	–
	(0.0352)	(0.1550)	(0.0285)	(0.0628)	(0.0822)	–
# of obs.	1497	1507	1521	1438	1469	1497
adj. R^2	0.0125	0.0084	0.0069	0.0070	0.0069	-0.0379
AIC	-8.5043	-8.3460	-8.0704	-7.3190	-8.9829	-11.0550
SIC	-8.4795	-8.3213	-8.0494	-7.2896	-8.9613	-11.0372

Note: standard errors are in parentheses; significance at 1%, 5%, and 10% level is denoted by a, b, and c superscript respectively.

Figure 3: Estimated conditional variance in the CEEC-6 group.

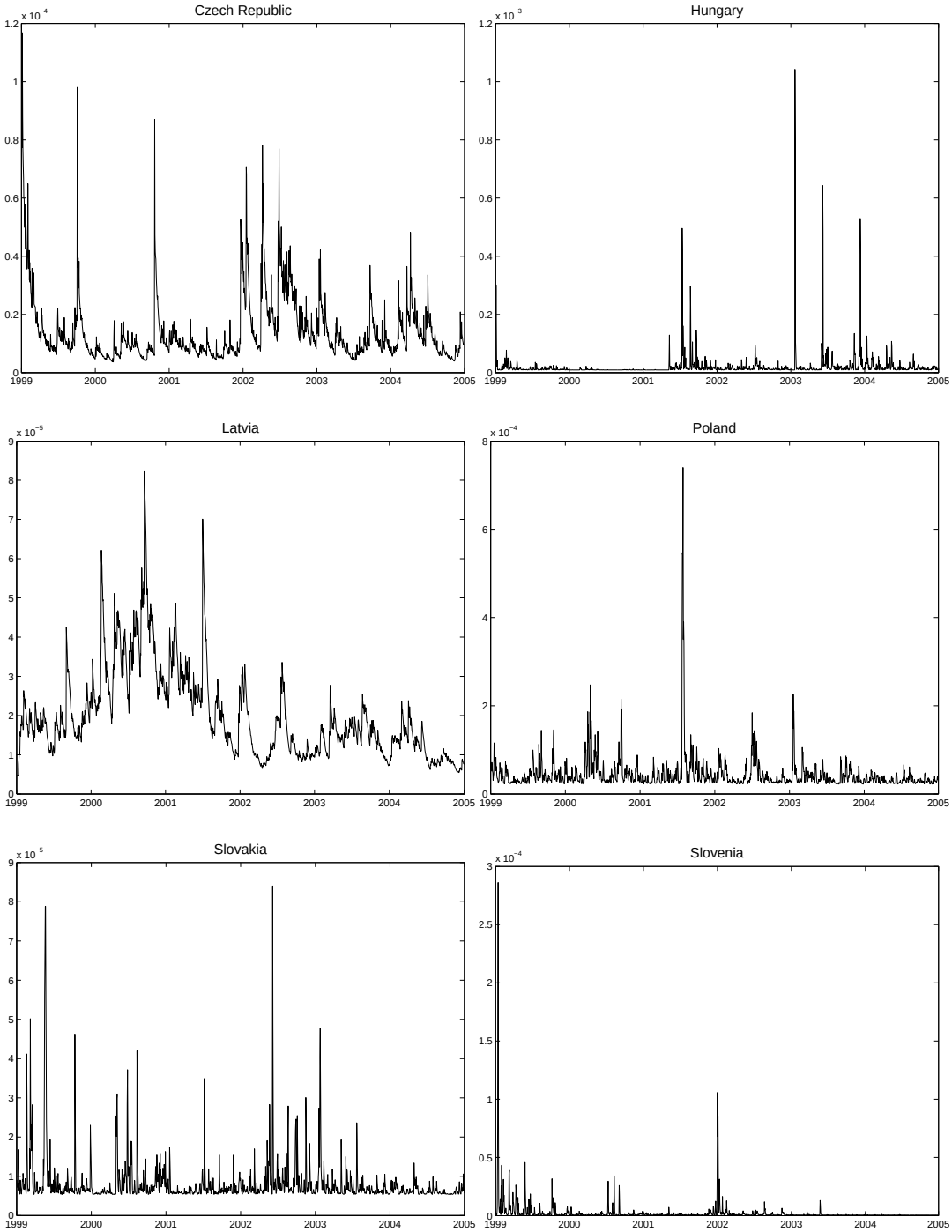


Table 5: Estimated conditional variance – data summary.

country	min	max	mean	st.dev.
Czech Republic	$3.68 \cdot 10^{-6}$	0.000117	$1.42 \cdot 10^{-5}$	$1.15 \cdot 10^{-5}$
Hungary	$9.12 \cdot 10^{-6}$	0.001042	$2.01 \cdot 10^{-5}$	$4.92 \cdot 10^{-5}$
Latvia	$4.62 \cdot 10^{-6}$	0.000082	$1.99 \cdot 10^{-5}$	$1.14 \cdot 10^{-5}$
Poland	$2.24 \cdot 10^{-5}$	0.000740	$4.42 \cdot 10^{-5}$	$3.98 \cdot 10^{-5}$
Slovakia	$5.37 \cdot 10^{-6}$	0.000084	$8.10 \cdot 10^{-6}$	$6.15 \cdot 10^{-5}$
Slovenia	$4.96 \cdot 10^{-7}$	0.000286	$2.28 \cdot 10^{-6}$	$1.03 \cdot 10^{-5}$

Table 6: Variable $NEWS$ – data summary.

country	min	max	mean	st.dev.	median
Czech Republic	−0.7872	0.3244	$-5.85 \cdot 10^{-16}$	0.0564	0.0033
Hungary	−12.3328	24.5462	$1.03 \cdot 10^{-14}$	1.9964	0.0222
Latvia	−1.3959	1.6170	$1.55 \cdot 10^{-16}$	0.1330	−0.0019
Poland	−1.9082	1.0049	$1.15 \cdot 10^{-15}$	0.1789	−0.0024
Slovakia	−6.4948	7.2563	$-4.19 \cdot 10^{-15}$	0.3832	0.0021
Slovenia	−2.1471	3.5324	$6.41 \cdot 10^{-16}$	0.4378	−0.0303

Note: a negative value indicates good news, a positive values indicates bad news.

sign of coefficient β corresponds to previously mentioned theory that countries with more open economies tend to have lower exchange rate volatility. The only exception here is Hungary with positive, but statistically insignificant, value of β. The effect of openness is insignificant also in the Czech Republic. On the other hand, openness has statistically significant effects on exchange rate volatility in the other four countries. The least effect is in Slovakia, where a 1% increase in the ratio of import over GDP decreases variance by 3.1% of its mean value. Bigger effects are in Poland (8.8%), Latvia (18.3%), and in Slovenia with its huge 98% decrease.

The results for regimes reflect natural expectations – less tight regime corresponds to higher volatility. In May 2001 Hungary changed its exchange rate regime from ±2.25% crawling band to ±15% and the results suggest that the former regime significantly lowers conditional variance by its mean value compared to the latter regime. In the case of Poland, a change of exchange rate regime from ±12.5% crawling band to ±15% has no significant effects on conditional variance with re-

spect to a base floating exchange rate regime. Similarly, in Slovenia a change from ±2% crawling band to Exchange Rate Mechanism II (ERM II) has no significant effects on volatility as well. It implies that Slovenia does not use the whole ±15% band that is allowed by ERM II.

As regards to the news effects[17], the results are mostly consistent with the results about the leverage effect from the TARCH model. The exceptions are Poland and Hungary with lagged effects of news. In both cases, the effects of good news are opposite to those estimated by leverage term from the TARCH model. The reason for this discrepancy may be that the TARCH model uses the residuals only from exchange rate changes, while the approach in equation (1) accounts for changes in expectations about exchange rates as well as interest rates. However, the complexity of this latter approach guarantees more accurate measures of the news effects. In all six countries, the results suggest that news statistically significantly impacts exchange rate volatility; there is no statistical significant difference between good and bad news in the level of the effect; and there are huge differences in vulnerability across the CEEC-6 group when taking into account the extreme values of estimated news. Good (bad) news increases (decreases) exchange rate volatility in the Czech Republic (about 30% of its mean), Latvia (less than 10% of its mean) and Poland (about half the mean). The situation is opposite in Slovakia, where good news decreases and bad news increases exchange rate volatility – by more than the mean of its exchange rate volatility. Hungary and Slovenia are the only countries, where any news, good and bad, increases exchange rates volatility; again, by more than the mean of their exchange rate volatility.

[17]Recall that a negative sign of coefficient γ in case of good news is interpreted such that it increases exchange rate volatility.

Table 7: Sources of exchange rate volatility – the results.

$$ERV_t = \alpha + \beta\left(\frac{Im_t}{GDP_t}\right) + \gamma_G G_t * NEWS_t + \gamma_B B_t * NEWS_t + \delta REGIME_t + \varepsilon_t$$

	Czech Rep.	Hungary	Latvia	Poland	Slovakia	Slovenia
α	$2 \cdot 10^{-5}$	$-1 \cdot 10^{-4}$	$2 \cdot 10^{-4a}$	$2 \cdot 10^{-4a}$	$3 \cdot 10^{-5a}$	$1 \cdot 10^{-4c}$
	$(3 \cdot 10^{-5})$	$(2 \cdot 10^{-4})$	$(4 \cdot 10^{-5})$	$(5 \cdot 10^{-5})$	$(8 \cdot 10^{-6})$	$(6 \cdot 10^{-5})$
β	$-1 \cdot 10^{-5}$	$3 \cdot 10^{-4}$	$-4 \cdot 10^{-4a}$	$-4 \cdot 10^{-4a}$	$-3 \cdot 10^{-5b}$	$-2 \cdot 10^{-4c}$
	$(6 \cdot 10^{-5})$	$(4 \cdot 10^{-4})$	$(8 \cdot 10^{-5})$	$(2 \cdot 10^{-4})$	$(1 \cdot 10^{-5})$	$(1 \cdot 10^{-4})$
γ_G	$-7 \cdot 10^{-6}$	–	–	–	–	–
	$(6 \cdot 10^{-6})$	–	–	–	–	–
$\gamma_{G\ lag\#1}$	–	–	–	$-7 \cdot 10^{-6b}$	–	–
	–	–	–	$(4 \cdot 10^{-6})$	–	–
$\gamma_{G\ lag\#3}$	–	–	–	–	$1 \cdot 10^{-6b}$	$-2 \cdot 10^{-6c}$
	–	–	–	–	$(4 \cdot 10^{-7})$	$(1 \cdot 10^{-6})$
$\gamma_{G\ lag\#5}$	–	$-4 \cdot 10^{-6c}$	–	–	–	–
	–	$(2 \cdot 10^{-6})$	–	–	–	–
$\gamma_{G\ lag\#8}$	–	–	$-1 \cdot 10^{-6}$	–	–	–
	–	–	$(7 \cdot 10^{-7})$	–	–	–
γ_B	–	–	$-1 \cdot 10^{-6c}$	–	–	–
	–	–	$(7 \cdot 10^{-7})$	–	–	–
$\gamma_{B\ lag\#3}$	–	–	–	–	–	$7 \cdot 10^{-7}$
	–	–	–	–	–	$(5 \cdot 10^{-7})$
$\gamma_{B\ lag\#4}$	–	–	–	–	$2 \cdot 10^{-6d}$	–
	–	–	–	–	$(1 \cdot 10^{-6})$	–
$\gamma_{B\ lag\#5}$	$-1 \cdot 10^{-5c}$	$4 \cdot 10^{-7d}$	–	–	–	–
	$(7 \cdot 10^{-6})$	$(3 \cdot 10^{-7})$	–	–	–	–
$\gamma_{B\ lag\#7}$	–	–	–	$-3 \cdot 10^{-5c}$	–	–
	–	–	–	$(1 \cdot 10^{-5})$	–	–
δ_{REG1}	–	$-1 \cdot 10^{-5a}$	–	$-2 \cdot 10^{-5}$	–	$-2 \cdot 10^{-6}$
	–	$(4 \cdot 10^{-6})$	–	$(2 \cdot 10^{-5})$	–	$(1 \cdot 10^{-6})$
δ_{REG2}	–	$-2 \cdot 10^{-5b}$	–	$-7 \cdot 10^{-6}$	–	–
	–	$(1 \cdot 10^{-5})$	–	$(8 \cdot 10^{-6})$	–	–
δ_{REG3}	–	$-8 \cdot 10^{-6}$	–	–	–	–
	–	$(1 \cdot 10^{-5})$	–	–	–	–
ρ	0.8511^a	0.5228^a	0.9586^a	0.8170^a	0.6993^a	0.6630^a
	(0.0310)	(0.1158)	(0.0094)	(0.1075)	(0.0550)	(0.2272)
# of obs.	1495	1506	1520	1437	1464	1493
adj. R^2	0.7405	0.2901	0.9454	0.6753	0.5303	0.4594

Note: standard errors are in parentheses; significance at 1%, 5%, 10%, and 15% level is denoted by a, b, c, and d superscript respectively. Parameter ρ is included to account for serial correlation in residuals.

6 Conclusion

In this paper I analyze the sources of euro exchange rate volatility in the CEEC-6 group. As possible sources, I am interested in the openness of an economy, the factor of news, and the exchange rate regime. Exchange rate volatility is estimated from TARCH model with accent on asymmetric effects of news. However, these asymmetric effects are confirmed only in the sense of their sign, not their value. This study further confirms the assumption that more open economies tend to have lower exchange rate volatility.

Looking at the results for particular countries, there is a large effect of news on exchange rate volatility in Hungary, Slovakia, and Slovenia. But Slovenia has a huge potential in its openness which has a substantial decreasing impact on its exchange rate volatility. On the other hand, Hungary and Slovakia cannot rely on such a tool because the openness has almost no effect on their exchange rate volatility. The other three countries, Latvia, Poland, and the Czech Republic, cannot rely on the openness in decreasing their exchange rate volatility as well, possibly except Latvia. However, these countries' exchange rate volatility is affected by news only slightly. Regarding regimes, only key changes in exchange rate regimes have significant effects on exchange rate volatility, while minor and superficial changes are not reflected in volatility at all.

The main contribution of this study is that it sheds some light on a few potential pitfalls that may occur during the CEEC-6 group's EMU integration process. The fact that vulnerability of these countries varies may be explained by the different strength of each country's currency or by different policies adopted by each country's central bank. Either way, further research is needed to able to distinguish between these two cases and to see their impact on other Maastricht criteria.

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