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EXCHANGE RATE VOLATILITY AND GROWTH IN EMERGING EUROPE

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Abstract. This paper analyses the influence of NEER and REER volatility on growth in a panel of six developing European countries. Two measures of volatility are employed (standard deviation and ARCH/GARCH models) and its influence on growth is tested both through a GLS and a GMM estimation. Moreover, given the properties of the time series used, both panel and individual cointegration are tested using the Pedroni and, respectively, the Johansen methodology.

1. Introduction

The international experience has highlighted the importance of the exchange rate dynamics in a country's economic evolution. The increase in capital circulation, the release of the derivatives, the costs of maintaining fixed exchange rate regimes are only few of the important factors substantiating the choice between a fixed exchange rate regime and a floating one combined with different monetary policy strategies. The choice is even more diffcult for the emerging economies where imports, exports and capital inflows have a significant weight. Hence, significant fluctuations of the exchange rate lead to signifcant fluctuations in the real economy, causing emerging economies to allow only moderate fluctuations of the nominal or real exchange rate, attitude known in the economic literature as *fear of floating*. According to some approaches, exchange rate volatility promotes economic growth by making monetary policy instruments flexible enough to soften asymmetric shocks (Meade, 1951, Friedman, 1953). On the other hand, some authors argue for the negative relation between these two, given the incertitude induced by the volatility in the macroeconomic environment and the ineffcient foreign exchange markets in developing economies (Altar et al., 2006).

Thereby, we intend to indentify the direction and quantify the influence of the exchange rate volatility on economic growth on a panel of six emerging economies: Czech Republic, Latvia, Poland, Romania, Turkey and Hungary. Moreover, we want to establish the role of financial development and to test the existence of a relationship in the long-run. The results we obtained are congruous to the part of the literature that argues for the negative influence that exchange rate volatility has on growth. Financial development doesn't have a significant role and cointegration tests show the absence of a long-run relationship.

The rest of this paper is structured as it follows: the first section consists of a literature review followed by a short description of the data and methodology used. The following section presents the volatility estimation results that are used in order to test the influence of the exchange rate volatility on economic growth and to identify a long-run relationship between the two variables. The last section concludes the main findings of the research.

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2. Literature Review

Increased capital mobility, increased costs of maintaining a fixed exchange rate, currency crises in emerging countries and the introduction of financial innovations are just some of the reasons that made many countries in transition to drop fixed exchange rate arrangements and to switch to free or controlled floating. Due to less developed capital markets, emerging countries are more exposed to exchange rate fluctuations because they lack the tools to protect against currency risk.

The Asian experience between 1997 and 1998 showed that countries have to choose either a scheme that ensures credibility, namely a fixed exchange rate (such as "hard peg") or a floating exchange rate regime combined with different monetary policy strategies. In 1961, Robert Mundell launched the optimum currency areas theory, according to which exchange rate regimes are measured in terms of effciency in helping to reduce the variability of gross domestic product. The applicability of this theory in developing countries is however questionable since fiscal, financial and monetary institutions are poorly developed and currency substitution and the dollarization of the economy increases vulnerability to a sudden stop in capital inflows. From this perspective, the key to the macroeconomic success of an emerging economy is not the initial choice of the exchange rate regime, but rather the "health" of the fundamental institutions of the state. Thus, institutional reform should be considered a priority rather than the choice between a fixed and a floating exchange rate regime.

The exchange rate has been the focus of macroeconomic discussions in emerging countries for decades. Here imports, exports and capital inflows have a significant weight, so that exchange rate fluctuations cause substantial fluctuations in the real economy. Under a floating exchange rate regime in a country where banks have loans denominated in foreign currency, a depreciation of the domestic currency would endanger the entire financial system. Hence the opposition of most developing countries to allow full exchange rate fluctuations, attitude known as *fear of floating* (Calvo and Reinhart, 2002).

Proponents of fixed exchange rate regimes argue that exchange rate stability promotes growth by ensuring macroeconomic stability and greater external trade (Frankel, Rose, 2001). Moreover, exchange rate flexibility supporters have highlighted the need for macroeconomic flexibility to cope with asymmetric shocks and boost aggregate demand (Meade, 1951, Friedman 1953). However, given that people's expectations are not stationary, exchange rate does not function as a tool for stabilizing asymmetric shocks , but rather tends to become an independent source of volatility that can be eliminated through early integration into a monetary union (Mundell, 1973a, 1973b). Exchange rate volatility is a source of ineffciency because foreign exchange markets are characterized by the presence of speculative actions. This leads to changes in exchange rate dynamics that do not result from the fundamentals.

Analyzing the performance of floating exchange rate regimes combined with inflation targeting versus fixed exchange rate regimes, Gali and Monacelli (2004) showed that the price paid by the adherents of the first category for the simultaneous stabilization of the output gap and inflation was a higher exchange rate volatility, both in nominal and real terms. In close connection with this, Bleaney and Francisco (2008) show that inflation targeting reduces the volatility of real exchange rate expectations, given the tendency of associating it with floating exchange rate regimes. Taking a look at the issue from the opposite angle, namely the influence of exchange rate volatility on inflation performance, the cross-country research conducted by Edwards (1993) showed that developing countries that have adopted a fixed rate regime obtained better inflationary performances than countries that practice schemes characterized by greater flexibility. Inflation is much lower and less volatile in peg regimes. Regarding growth, few systematic differences related to exchange rate regime have been found (Ghosh et al., 1995).

Another series of working papers emphasizes the role of a state's financial development in assessing the influence of exchange rate volatility on growth. Differences given by the level of development occur primarily in the exchange rate volatility as an independent variable. Ganguly and Boucher (2009) argue that the latter is higher in developing countries than in industrialized countries due to the action of numerous factors such as shocks in terms-of-trade, high volatility of gross domestic product therefore limiting the ability to deal with fiscal and monetary shocks, nominal shocks with stronger effects due to lack of credible monetary institutions and weak fiscal positions, exposure to suddenstops in capital flows. Growth variable entering the equation, there is a negative relationship between productivity growth and exchange rate volatility in less financially developed countries and there is no link between the two in developed countries (Aghion et al., 2006). In close connection to the above mentioned, Schnabl (2007a) shows that exchange rate stability exerts a negative influence on growth in developing states because it doesn't allow them to react flexibly to real shocks and stimulates speculative capital inflows. On the other hand, it carries a positive influence on economic growth as it leads to lower transaction costs in international trade, decreases the uncertainty of capital flows and stimulates international macroeconomic stability.

However, the results of empirical analysis overwhelmingly depend on the timeframe and the sample of countries chosen. From this perspective the results are sometimes contradictory: Ghosh et al. (2003) reported the existence of weak links between exchange rate volatility and growth, Edwards and Levy-Yeyati (2003) argue that a floating exchange rate regime provides a faster economic growth and Eichengrenn and Leblang (2003) show that there is a negative link between exchange rate stability and growth.

3. Data and Methodology

3.1. **Description of the dataset.** Following Schnabl's (2007) model, we started from a sample of 17 states from which those who have adopted a fixed scheme have been removed. Later, under the constraint of data availability, the sample was reduced to a number of six countries: Romania, Hungary, Poland, Czech Republic, Latvia and Turkey. A first problem in setting up the database is the choice of the exchange rate whose volatility will be calculated. Although the *bilateral exchange rate* is available with daily frequency, we preferred using the *effective exchange rate*,[1] the latter having the advantage of being able to capture the relationships with trading partners. For a complete capture of the interdependencies, both the nominal exchange rate and the real are submitted to analysis. A second problem is the quantification of economic growth. Indicators using gross domestic product are available only with quarterly frequency, which significantly reduces the size of the sample and therefore the robustness of future results. Thus it is necessary to establish a proxy for growth and from the experience of previous studies, the best option is the industrial production index, available monthly. However, the latter has a significant drawback since it accounts for approximately 30% of the GDP of the considered countries. Another purpose of this study is to capture the role of financial development in the relationship between exchange rate volatility and economic growth. Starting from the proposals of the existing literature for the quantification of the financial development, monthly frequency observations are needed on the ratio M3 to GDP.

3.2. **Methodology.**

3.2.1. *Volatility estimation.* The estimation of exchange rate volatility can be achieved through a number of ways, from structural models and to specific time series processes. The most commonly used method of measuring exchange rate volatility is to calculate the *standard deviation* of the first differences of the exchange rate, in logarithm. The volatility of the exchange rate based on standard deviation may be determined by using the moving average or exponentially weighted moving average method. However, most financial series that are characterized by the

[1]The effective exchange rate is calculated according to the methodology proposed by DG ECFIN. According to it, the nominal effective exchange rate is calculated as a geometric weighted average of the exchange rates of the countries engaged in bilateral trade relations and the real effective exchange rate is obtained by deflating the nominal effective exchange rate with the cost of labor unit cost and the consumer prices index.

fact that their conditional variance is not constant over time,[2] which is why modeling tools that describe the evolution of the error variance must be used. Another feature of these time series is the phenomenon of volatility clustering, that is the current level of the volatility is positively correlated with the level of the immediately prior volatility. It was also noted that the negative returns associated with different financial assets have a higher volatility than positive ones, phenomenon known as the asymmetry of volatility (Black, 1976). From this point of view, it appears more feasible an estimation of volatility through *specific time series models*.

Let's take y_t for analysis, assuming that:

$$y_t = E(y_t/y_{t-1} + \varepsilon_t) \tag{3.1}$$

where $E(y_t/y_{t-1})$ is the conditional mean and ε_t is a stochastic process that satisfies the following: $E(\varepsilon_t) = 0$ and $E(\varepsilon_i \varepsilon_j) = 0, i \neq j$.

The ARCH process introduced by Engle (1982) introduces the idea of the difference between the unconditional and conditional variance, defining the latter as a function of past errors. Therefore, the $ARCH(q)$ model implies that the conditional variance depends on the squared residuals from the conditional mean's equation:

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1} + ... + \alpha_q \varepsilon_{t-q} \tag{3.2}$$

where $\varepsilon_t \sim N(0, \sigma_t), \alpha_i \geq 0$.

It was later found that in order to capture the dynamics of the conditional variance through ARCH processes the estimation of a large number of parameters was needed. Therefore, Bollerslev (1986) introduced the GARCH process (Generalized Autoregressive Conditional Heteroskedasicity) that allows conditional variance models using fewer parameters. In defining GARCH models we use the idea that the variance is not constant in time which allows the following: $\varepsilon_t = z_t \sigma_t$, where z_t *i.i.d.* and σ_t is the conditional variance. Therefore, the conditional variance equation becomes:

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{p} \beta_j \varepsilon_{t-j}^2 \tag{3.3}$$

where $\alpha_i \geq 0, \beta_j \geq 0$.

If $\Sigma_{i=1}^q \alpha_i + \Sigma_{j=1}^p \beta_j \geq 1$, then the influence of σ_t^2 on σ_{t+h}^2 is stored for large values of h, phenomenon known as *persistence in volatility*. The latter can be modeled using an *IGARCH (p,q)* process, which implies that $\Sigma_{i=1}^q \alpha_i + \Sigma_{j=1}^p \beta_j = 1$. Therefore, the equation of the conditional variance becomes:

$$\sigma_t^2 = \alpha_0 (1 - B(L))^{-1} + [1 - C(L)(1 - L)[1 - B(L))]^{-1}] \varepsilon_t^2 \tag{3.4}$$

where $A(L) = \Sigma_{i=1}^q \alpha_i L^i$ and $B(L) = \Sigma_{j=1}^p \beta_j L^j$ are invertible and $C(L) = (1 - A(L) - B(L)](1 - L)^{-1}$.

Another approach to GARCH models raises the possibility of the existence of a leverage. A useful model is the EGARCH model (exponential GARCH), introduced by Nelson (1991), in which the conditional variance has the following equation:

$$\ln \sigma_t^2 = \alpha_0 + A(L)(\gamma_1 \frac{\varepsilon_t}{\sigma_t} + \gamma_2 (|\frac{\varepsilon_t}{\sigma_t}| - E(|\frac{\varepsilon_t}{\sigma_t}|))) + B(L) \ln \sigma_t^2 \tag{3.5}$$

where $E(|z_t|)$ depends on the form of the distribution.

Following the standard convention, the analysis will use the return of the effective exchange rate rather than its logarithmic expression or its absolute value:

$$R_t = 100 \times (\ln x_t - \ln x_{t-1}) \tag{3.6}$$

where is the nominal or real effective exchange rate at time t.

[2]Conditional heteroskedasticity (Fama, 1965).

3.2.2. *Panel estimation. GLS and GMM.* Estimations made with panel data have the advantage of enabling the summarizing of the impact of a variable on a group of dependent variables in a single coeffcient, the estimation of specifc coeffcients for each dependent variable (fixed effects) and the grouping of dependent variables into categories and the estimation of the impact of the category's evolution on a specific dependent variable. It is likely that in cross-sectional analysis the error variances vary across the groups affecting the consistency of the estimators. Therefore, a solution is using the *generalized least squares method* (GLS) in the estimation. However, there might still exist other sources of variance variability represented by the correlation of the squared residuals with the regressors in each group. The first source of within-group heteroskedasticity is given by differences in the unconditional variance of the residual terms while the second one is given by differences in the variance of the residual terms conditioned on the regressors. To control for both heteroskedaticity sources, a more effcient estimator is the one using the *generalized method of moments* (GMM). Thus, GLS is equivalent with GMM using a restrictive matrix that assumes the absence of conditional heteroskedacticity. Hence, we can infer the superiority of GMM (that uses a non-restrictive matrix) on GLS (that uses a restrictive matrix) in the case of heteroskedasticity conditioned on the regressors presence.

Considering the model:

$$Y_{it} = \alpha + X'_{it}\beta + \delta_i + \gamma_t + \epsilon_{it} \tag{3.7}$$

where $i = \overline{1, N}$, $t = \overline{1, T}$, Y represents the dependent variables, α is a number, X represents the independent variables, β represents the parameters, ϵ_{it} represents the residual terms, δ_i and γ_t are the cross-section and, respectively period fixed or random effects, the GLS estimator is based on the following moments:

$$g(\beta) = \sum_{i=1}^{M} g_i(\beta) = \sum_{i=1}^{M} Z'_i \widehat{\Omega}^{-1} \epsilon_i(\beta) \tag{3.8}$$

where Z'_i is the instrument matrix for the i-th cross-section, $\epsilon_i(\beta) = (Y_{it} - \alpha - X'_{it}\beta)$ and $\widehat{\Omega}$ is a consistent estimator of the variance-covariance matrix Ω.

Corespondingly, the GMM estimator is based on the following:

$$g(\beta) = \sum_{i=1}^{M} g_i(\beta) = \sum_{i=1}^{M} Z'_i \epsilon_i(\beta) \tag{3.9}$$

and solves the following minimization problem, function of β:

$$S(B) = (\sum_{i=1}^{M} Z'_i \epsilon_i(\beta))' W (\sum_{i=1}^{M} Z'_i \epsilon_i(\beta)) = g(\beta)' W g(\beta) \tag{3.10}$$

3.2.3. *Panel cointegration.* Using non-stationary time series in econometric estimates a_ects the asymptotic distribution of test t. Using unit root differentiation to eliminate this can lead to long-term loss of information included in the original form of the data. Engle and Granger (1987) showed that a linear combination of at least two such series can be stationary. In this case, the original series are considered to be cointegrated and the stationary linear combination obtained can be interpreted as the longterm relationship between them. In close connection with the above stated, Johansen (1991, 1995) suggests a method of testing the existence of cointegration relations starting from a VAR of order p:

$$y_t = A_1 y_{t-1} + ... + A_p y_{t-p} + B x_t + \epsilon_t \tag{3.11}$$

where y_t is the k-vector of the *I(1)* variables, x_t is the vector of the deterministic variables and ϵ_t is the innovations vector.

The VAR can be rewritten as:

$$\Delta y_t = \Delta y_{t-1} + \sum_{i=1}^{p-1} \Gamma i y_{t-i} + B x_t + \epsilon_t \tag{3.12}$$

where $\Pi = \Sigma_{i=1}^{p} A_i - I$ and $\Gamma i = -\Sigma_{j=i+1}^{p} A_j$. If the coefficient matrix Π has reduced rank $r < k$, then there exist $k \times r$ matrices α and β, each with rank r, such that $\Pi = \alpha\beta'$ and $\beta' y_t$ is *I(0)*. r is the *contegrating rank*, each column of β is the cointegrating vector and the elements of α are known as the adjustment parameters in the VEC model. Johansen's methodology estimates the Π matrix from an urestricted VAR and testes whether $r < k$.

Unlike in individual cointegration, panel data analysis rises problems such as data heterogeneity, cross-sectional dependence, the number of cross-sections (N), the observation period (T). Gutierrez et al. (2003) argues that for panels with a large T the Pedroni cointegration test (Pedroni, 1999, 2004) works better than for panels with a small T for which the Kao test (Kao, 1999) is more appropriate. Cosidering:

$$y_{it} = \alpha_i + \delta_i t + \beta_{1i} x_{1i,t} + ... + \beta_{Mi} x_{Mi,t} + \epsilon_{i,t} \tag{3.13}$$

where y and x are *I(1)*, Pedroni proposes a test for cointegration that allows for heterogeneous effects and trends in cross-section. The null hypothesis is the lack of cointegration between the variables considered, for which the $\epsilon_{i,t}$ is *I(1)*. The Pedroni test involves the use of the previously obtained residuals to test whether they are *I(1)* or not by estimating, for each cross-section, the following equation:

$$\epsilon_{i,t} = \rho_i \epsilon_{i,t-1} + u_{i,t} \tag{3.14}$$

Under the null hypothesis $\rho_i = 1$. To test this Pedroni suggests different ways of calculating the statistic tests either from a homogeneous approach ($\rho_i = \rho < 1$ for all the cross-sections) or from a heterogeneous one ($\rho_i < 1$ for all the cross-sections), generating a total of 11 statistic tests with different properties function of N and T.

4. Empirical Results

4.1. **Exchange rate volatility estimation.** In order to estimate the monthly volatility of the effective exchange rate of the currencies countries considered, we used two methods:

- volatility estimation based on calculating the standard deviation of the first difference of the exchange rate, in logarithm. In this case, the volatility was calculated as the *standard deviation* of a 60 months rolling window, corresponding to monthly exchange rate changes.
- volatility estimation based on *ARCH/GARCH models*. Regarding volatility measurement using such processes, daily observations are recommended. Since observations on real and nominal effective exchange rates had been available with monthly frequency, they were used as such, and the volatility estimation obtained was properly assessed and compared to that of the one based on the standard deviation.

4.1.1. *Exchange rate volatility estimation based on standard deviation.* The length of the rolling window was set at a total of 60 observations corresponding to the five years preceding the analyzed period. Therefore, volatility estimates measured by standard deviation were obtained using the observations from 1995 onwards (Figure 1 and Figure 2).

4.1.2. *Exchange rate volatility based on ARCH/GARCH models.* For all the exchange rates considered, the first step was to estimate the classical GARCH (1,1) model. If the validity criteria[3] haven't been confirmed, other GARCH models with parameters p and q were estimated , assuming that $p, q \leq 2$. If such estimated GARCH models haven't proven to be effcient, the coverage was expanded to a range of assumptions that meet the requirements of the series used. Therefore, for those models for which the coeffcients of the ARCH and GARCH terms did not ful_ll the condition of non-negativity, EGARCH models were estimated. The latter have the advantage of not being linear and they estimate the logarithm of the conditional variance and not the conditional variance itself as GARCH models do, capturing leverage effects and reducing the number of the constraints on the parameters. For the cases of persistence in

[3]Statistical significance of the parameters, existence of ARCH/GARCH residual effects, error distribution.

volatility models that capture this property have been estimated, namely integrated GARCH type models (IGARCH) (Table 1-2).

Figures 3 and 4 present the monthly volatility of the NEER and REER estimated by the method of moving averages compared to monthly volatility estimated by GARCH models. It is noted that the two have similar trend, managing to simultaneously identify the periods of growth and decrease of the nominal effective exchange rate volatility for all six currencies considered.

By analyzing the evolution of effective exchange rate volatility, it is noted that 2008 marked the beginning of an upward trend of exchange rate deviations from long-term trend in all the considered states. Therefore, the instability that began to characterize the macroeconomic environment after the outbreak of the economic crisis resulted in an unstable level of the exchange rates of the emerging economies' currencies. Later, because of the widening imbalances, in 2009-2010 emerging countries have experienced signi_cant reductions in rates or even negative growth. From this point of view, we may expect to find an inverse relationship between the exchange rate volatility and the pace of growth of a developing state, a higher volatility having an inhibitory role on the latter. Both in the case of NEER and REER it can be seen that the volatility measured through the method of moving averages is smoother than the volatility obtained by estimating GARCH models. Volatility methods based on moving averages may not fully reflect exchange rate fluctuations in the same period. This deficiency reduces the informational power of the results obtained, which is why it is preferable to use the two methods combined in future empirical analysis.

4.2. **Exchange rate volatility and growth.**

4.2.1. *GLS estimation.* Since the relationship between exchange rate volatility and growth is studied in a sample of emerging economies, each with its features related to the currency regime, the monetary policy and the level of financial development, their influence on the economic behavior of these countries is a subject of analysis. If the case in which such aspects are correlated with the model's explanatory variable, according to Baltagi (2005) and Greene (2002), the best approach is to estimate a model with *fixed effects*. The interest to quantify the influence of exchange rate volatility on economic growth across the entire group of countries, but also to measure the overall performance observed at individual level, reinforces the idea of estimating a model with cross-section fixed effects.

Table 3 presents the results of the GLS estimation of the influence of exchange rate volatility measured by standard deviation on growth. The analysis reveals a negative relationship between effective exchange rate volatility and economic growth. The estimated coeffcients are significant at 5% significance threshold. Analyzing the intensity of the relationship it can be seen that REER has a stronger influence on growth than NEER. This can be translated into the fact that an increase of the NEER volatility leads to a reduction of the industrial production index at a lower rate than the reduction caused by a potential increase of the REER volatility.

Table 4 presents the results of the GLS estimation of the influence of exchange rate volatility estimated with ARCH/GARCH models on growth. They confirm the negative influence on exchange rate volatility in growth for 1% and 5% thresholds. The panel estimation results show that a 1% increase on NEER volatility reduces economic growth by 0.24% and an increase of the REER volatility by the same percentage reduces economic growth by 0.41%.

4.2.2. *GMM estimation.* Arellano and Bond's GMM estimator supports the use of instrumental variables and the elimination of the heterogeneous characteristics of the model, given by the fixed and random effects, by applying the first difference. Hence, the influence of exchange rate volatility on growth has been captured both through exactly-identified and through over-identified models.

Tables 5 and 6 present the results of the GMM estimation concerning the influence of the exchange rate volatility estimated through the standard deviation on growth, both by exactly and over-identified models. The analysis confirms once again the negative influence of NEER and REER volatility on growth. However, the coeffcient estimated for the REER volatility in the case of the exactly-identified models is not statistically significant. If the NEER volatility, however, increases it would reduce the economic growth approximately to the same extent as identified in the GLS estimation. The estimation of the overidentified models enabled a conclusion in what concerns the impact of REER volatility on growth, using six instruments whose validity has been confirmed by the *J-statistic* for 1%, 5% and 10% thresholds.

Tables 7 and 8 summarize the findings of the GMM estimation that uses the exchange rate volatility estimated through GARCH models as an independent variable in the model. For the case of the exactly-identified models (Table 7) the coeffcient estimated for the NEER volatility is signi_cant for a 5% threshold while the one for REER volatility is significant for a 10% threshold. Following the trend shown by the GLS estimation, the influence of the REER volatility on growth is stronger than the one of NEER volatility, an 1% increase of the real exchange rate volatility causing a 0.55% reduction of the growth rate compared to the approximately 2% reduction caused by a 1% increase of the nominal exchange rate volatility. The over-identified dynamic panel (Table 8) confirms the negative influence of exchange rate volatility on growth, stronger in the case of REER volatility.

4.2.3. *The role of financial development.* Aghion et al. (2006) argue on the importance of a state's level of financial development in choosing the flexibility degree of the foreign exchange regime, given its long-term goal to increase productivity. The reviewed literature sugests two measures of financial development:

$$FD = \ln \frac{PC}{GDP}$$

where FD stands for the level of financial developmet and PC is the credit given to the private sector (Aghion et al., 2006 and Arratibel et al., 2009) and

$$FD = \ln(1 + \frac{M_3}{GDP})$$

measure used by Bleaney and Francisco (2008).

The scarcity of data on the credit given to the private sector makes it diffcult to quantify the role of financial development, measured as the ratio between the latter and the gross domestic product, in the relationship between exchange rate volatility and economic growth. Therefore, the attention is directed towards the second measure of financial development, which allows for a robust estimate. Similar to the results of Bleaney and Francisco (2008), the introduction of the financial development in the equation that defines the link between exchange rate volatility and economic growth , either as an instrument or as explanatory variable, or both, confirms the negative relationship, but the estimated coeffcients are statistically insignificant at a threshold of 10%. This conclusion contradicts the results of Aghion et al. (2006) in terms of statistical significance of the estimated coefcients (Table 9). An explanation for this contradiction is the use of diferent measures of financial development or the failure of these measures to capture all aspects that define the financial development.

4.3. **Cointegration evidence.**

4.3.1. *Panel cointegration.* The panel unit-root tests conducted have shown the fact that the series representing the industrial production index and the exchange rate volatility measured by standard deviation do have a unit root, thus enhancing the idea of panel cointegration testing (Table 10). The Pedroni cointegration test calculates a total of 11 statistics to check the null hypothesis of no cointegration. This critical value is -1.64 (except v-statistic whose critical value is 1.64). In other words, calculated test values less than -1.64, respectively higher than 1.64 for v-statistics, show the existence of a cointegration relationship between the considered variables. Given the trend of the industrial production index in calculating the statistics we allowed for a trend and an intercept in the crosssections. Table 11 shows that only 2 of the 11 calculated statistics confirm a long-term relationship between NEER volatility and growth for a 5% threshold while all of them indicate no cointegration between REER volatility and growth.

4.3.2. *Cross-section cointegration.* Following the example of the analysis performed by Sahan and Bektasoglu (2010) and Alam et al. (2010), panel cointegration testing is accompanied by testing for long-term relationships between the analyzed variables in each cross-section. Prior to the cointegration test itself, estimating an unrestricted VAR allowed establishing the lag length structure based on Akaike, Schwarz and Hannan-Quinn informational criteria. The Johansen cointegration test confirmed the results obtained in panel cointegration test, reinforcing the idea of the lack of a long-term relationships between exchange rate volatility and economic growth in the developing countries considered (Table 12).

5. Conclusion

The economic literature highlighted the link between the exchange rate regime and the economic performance of a country. Considering growth an exponent of economic performance, the problem of quantifying the link between the latter and the exchange rate movements emerges.

A first step was to estimate the volatility of real and nominal exchange rate against the euro both by using structural methods (method of moving averages, standard deviation) and specific time series models (models ARCH / GARCH). The results obtained showed similar evolution of the volatility estimated by both methods. However, differences have arisen showing that both results should be used in subsequent estimates.

The econometric testing of the relationship between exchange rate volatility and growth used both GLS and GMM method. GLS estimations revealed the existence of a negative link between exchange rate volatility and economic growth at a 5% threshold. The intensity of the link is higher in the case of REER volatility and a change in the evolution of the exchange rate volatility affects growth significantly stronger than the exchange rate volatility itself. GMM estimations confirmed the results of the GLS estimation, with minor differences related to the relationship's intensity and the threshold for the estimated coefficients' statistical significance.

A third step was the introduction in the analysis of the level of financial development of considered states in order to quantify its role in the sense or intensity of the link between exchange rate volatility and economic growth. This part of the analysis confirmed the negative sense of the relationship, but without statistically significant estimated coeffcients.

Given the nonstationary nature of the series representing growth and exchange rate volatility estimated by structural methods, a last step of the analysis was to test the existence of a relationship between the two in the log-run. Panel estimates revealed the absence of a cointegration relationship between NEER and REER volatility and economic growth. Following the literature's suggestion, the existence of such relationship has been tested at cross-sectional level too, con_rming the absence of cointegration.

The complexity of the relationship between exchange rate volatility and growth requires the inclusion in the analysis of developed countries with floating exchange rate regimes and the comparison between the influence of exchange rate volatility on growth in those countries with results obtained for emerging economies.

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Appendix

Figure 1. NEER volatility measured by standard deviation

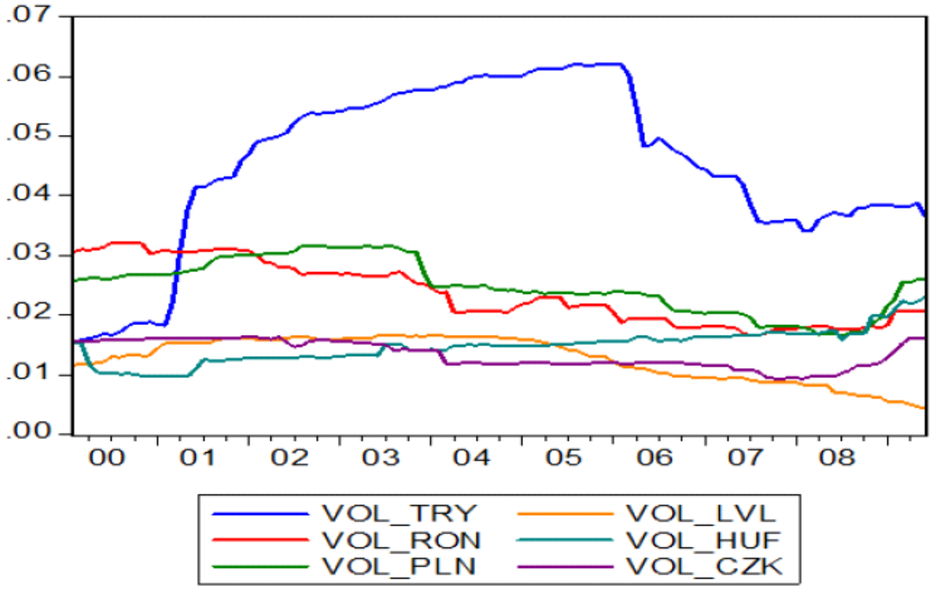

Figure 2. REER volatility measured by standard deviation

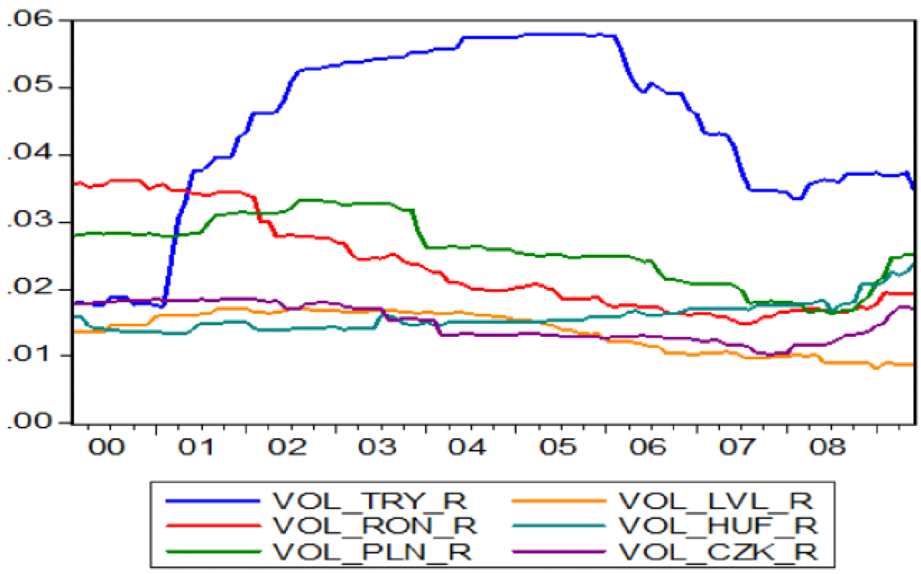

Table I. NEER volatility estimation

	Model	Variable	Coefficient	p-value	Error Distribution
Czech Republic	ARCH(1)	C	0.99E-05	0.0000***	Normal
		RESID(-1)^2	0.4636	0.0190**	
Latvia	EGARCH(1,1,2)	C	-1.3190	0.0000***	GED with fixed parameter
		RESID(-1)^2	0.9529	0.0000***	
		γ_1	-0.4077	0.0743*	
		γ_2	0.2972	0.0535*	
		GARCH(-1)	0.9394	0.0000***	
Poland	GARCH(1,2)	C	0.0005	0.0189**	Normal
		RESID(-1)^2	0.4160	0.0091***	
		RESID(-2)^2	0.4063	0.0449**	
		GARCH(-1)	-0.6638	0.2090	
Romania	EGARCH(1,1,1)	C	-8.9275	0.0010***	Asymmetric Student
		RESID(-1)^2	0.6635	0.0374**	
		γ_1	-0.1483	0.4614	
		GARCH(-1)	-0.0899	0.8056	
Turkey	EGARCH(1,2,1)	C	-7.4462	0.0004***	Student
		RESID(-1)^2	0.3784	0.3176	
		RESID(-1)^2	0.7349	0.1064	
		γ_1	-0.5658	0.0385**	
		GARCH(-1)	-0.0601	0.8445	
Hungary	GARCH(1,1)	C	8.12E-06	0.0415**	Student
		RESID(-1)^2	0.1070	0.0058***	
		GARCH(-1)	0.8981	0.0000***	

Table II. REER volatility estimation

	Model	Variable	Coefficient	p-value	Error Distribution
Czech Republic	GARCH(2,1)	C	3.15E-06	0.3942	Normal
		RESID(-1)^2	0.0540	0.0893*	
		GARCH(-1)	1.7358	0.0000***	
		GARCH(-2)	0.7972	0.0000***	
Latvia	IGARCH(1,1)	RESID(-1)^2	0.0685	0.0119**	Student
		GARCH(-1)	0.9314	0.0000***	
Poland	GARCH(2,1)	C	0.0001	0.0499**	Normal
		RESID(-1)^2	0.2517	0.0491**	
		GARCH(-1)	0.9031	0.0068***	
		GARCH(-2)	0.3974	0.0720*	
Romania	GARCH(1,1)	C	3.19E-05	0.3996	Normal
		RESID(-1)^2	0.0405	0.4658	
		GARCH(-1)	0.8664	0.0000***	
Turkey	Turkey	C	0.0004	0.0727*	GED with fixed parameter
		RESID(-1)^2	0.2101	0.0908*	
		GARCH(-1)	0.5600	0.0033***	
Hungary	IGARCH(1,1)	RESID(-1)^2	0.1400	0.0000***	Student with fixed parameter
		GARCH(-1)	0.8599	0.0000***	

Figure 3. NEER monthly volatility estimation. Moving average vs. ARCH/GARCH

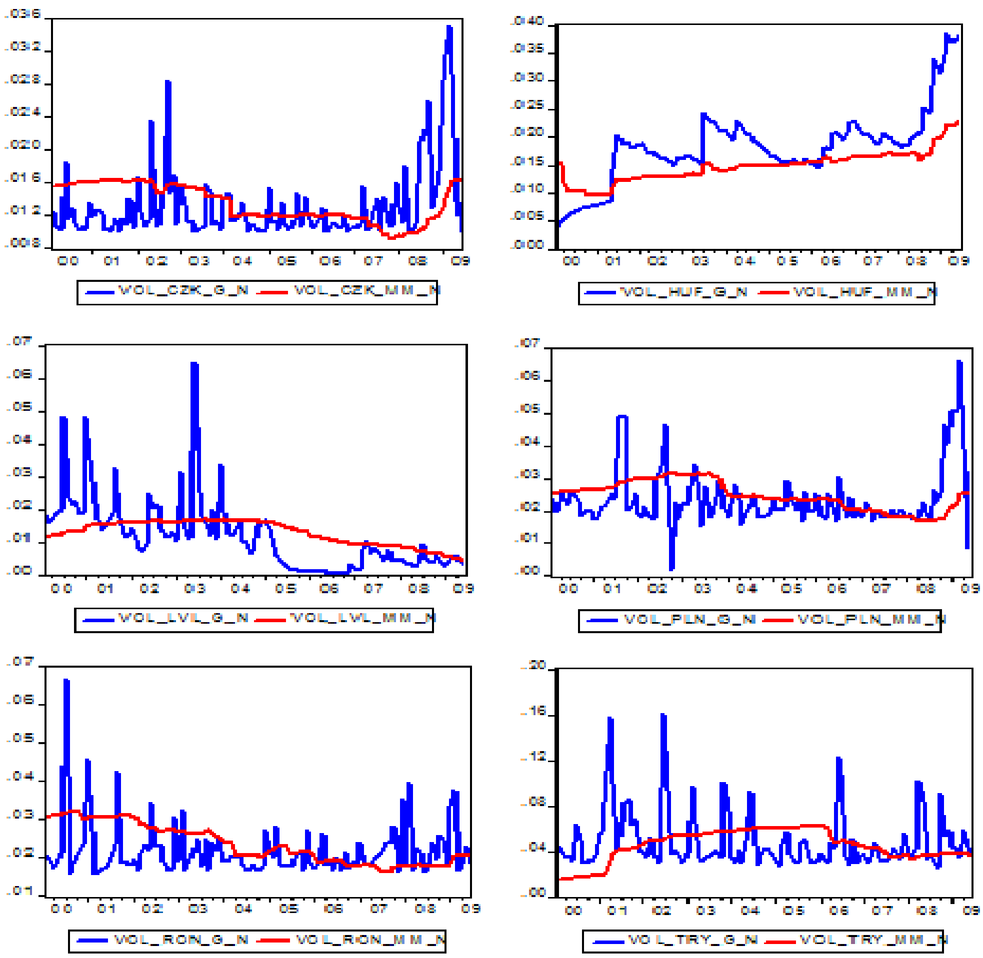

Figure 4. REER monthly volatility estimation. Moving average vs. ARCH/GARCH

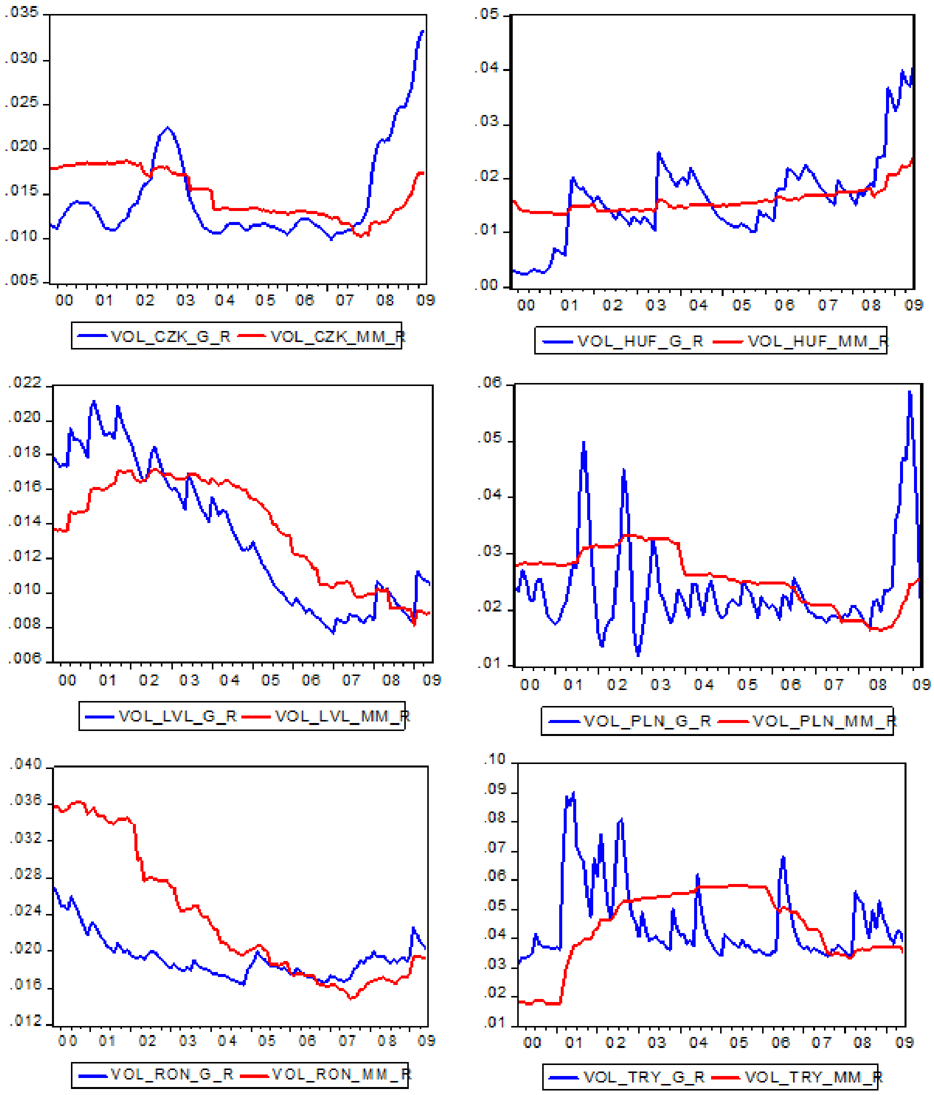

Table III. Exchange rate volatility (moving average) and growth. GLS estimation

	Coeffcient	Standard error	t-statistic	p-value
NEER volatility	3.6627	1.4781	-2.4779	0.0135**
REER volatility	-4.2299	1.7739	-2.3845	0.0174**

Table IV. Exchange rate volatility (ARCH/GARCH models) and growth. GLS estimation

	Coeffcient	Standard error	t-statistic	p-value
NEER volatility	-0.2482	0.0877	-2.8311	0.0048***
REER volatility	-0.4105	0.2009	-2.0434	0.0414**

Table V. Exchange rate volatility (moving average) and growth. GMM estimation. Exactly-identified models

	Coeffcient	Standard error	t-statistic	p-value
NEER volatility	-4.5674	1.0818	-4.2222	0.0000***
REER volatility	-3.1384	2.6021	-1.2061	0.2282

Table VI. Exchange rate volatility (moving average) and growth. GMM estimation. Over-identified models

	Coeffcient	Standard error	t-statistic	p-value
NEER volatility	-13.2189	6.5376	-2.0219	0.0436**
REER volatility	-8.7972	3.8274	-2.2986	0.0219**

Table VII. Exchange rate volatility (ARCH/GARCH models) and growth. GMM estimation. Exactly-identified models

	Coeffcient	Standard error	t-statistic	p-value
NEER volatility	-2.0999	0.8588	-2.4452	0.0147**
REER volatility	-6.5503	3.9582	-1.6549	0.0984*

Table VIII. Exchange rate volatility (ARCH/GARCH models) and growth. GMM estimation. Over-identified models

	Coeffcient	Standard error	t-statistic	p-value
NEER volatility	-0.8259	0.0741	-11.1438	0.0000***
REER volatility	-5.3341	1.5500	-3.4413	0.0006***

Table IX. Exchange rate volatility and growth. The role of financial development

	Exchange rate volatility	Economic growth (-1)	Financial development
NEER (moving average)	-1.7039 (0.8628)	-0.3938 (0.0000)***	-0.2772 (0.3045)
REER (moving average)	-2.9361 (0.9543)	-0.4349 (0.0458)**	0.0093 (0.9891)
NEER (ARCH/GARCH)	-0.0158 (0.9900)	-0.9523 (0.0000)***	1.2218 (0.0000)***
REER (ARCH/GARCH)	-0.8857 (0.9225)	-0.3976 (0.0017)***	-0.2628 (0.5714)

Table X. Panel unit-root tests

	IPS		ADF		PP		Result
	Level	1st difference	Level	1st difference	Level	1st difference	
Industrial production index	0.6105 (0.7292)	-6.2664 (0.0000)***	6.2945 (0.9005)	64.8441 (0.0000)***	7.8013 (0.8005)	428.08 (0.0000)***	I(1)
NEER volatility (moving average)	1.7326 (0.9584)	-6.0486 (0.0000)***	6.5101 (0.8882)	63.6992 (0.0000)***	5.4135 (0.9427)	254.39 (0.0000)***	I(1)
REER volatility (moving average)	2.0168 (0.9781)	-7.2713 (0.0000)***	7.0269 (0.8558)	80.3635 (0.0000)***	5.7084 (0.9301)	314.92 (0.0000)***	I(1)
NEER volatility (ARCH /GARCH)	-4.7644 (0.0000)***		59.7691 (0.0000)***		170.605 (0.0000)***		I(0)
NEER volatility (ARCH /GARCH)	-1.5387 (0.0619)*		26.6519 (0.0000)**		26.6394 (0.0000)**		I(0)

Table XI. Pedroni test

NEER volatilitty and growth		NEER volatilitty and growth	
Name of the statistics	Value (probability)	Name of the statistics	Value (probability)
Panel v	0.5605 (0.2876)	Panel v	0.1432 (0.4430)
Panel rho	-2.0675 (0.0193)**	Panel rho	-0.4425 (0.3291)
Panel PP	-1.9483 (0.0257)**	Panel PP	-0.2142 (0.4152)
Panel ADF	-0.0548 (0.4781)	Panel ADF	2.0143 (0.9780)
Panel v	0.2892 (0.3862)	Panel v	0.1011 (0.4597)
Panel rho	-0.8744 (0.1909)	Panel rho	0.1222 (0.5486)
Panel PP	-0.8296 (0.2059)	Panel PP	0.4312 0.4312
Panel ADF	0.6388 (0.7385)	Panel ADF	2.1832 (0.9855)
rho group	-0.6912 (0.2447)	rho group	0.2412 (0.5953)
PP group	-0.5595 (0.2879)	PP group	0.6834 (0.7528)
ADF group	0.7008 (0.7583)	ADF group	2.3640 (0.9910)

Table XII. Johansen cointegration test

	NEER				REER			
	Trace test		Max-eigenvalue test		Trace test		Max-eigenvalue test	
	r = 0	r≤1	r = 0	r≤1	r = 0	r≤1	r = 0	r≤1
Czech Republic	11.06 (0.87)	3.19 (0.85)	7.86 (0.83)	3.19 (0.85)	10.8 (0.88)	2.42 (0.94)	8.38 (0.79)	2.42 (0.94)
Latvia	40.59 (0.00)***	8.40 (0.22)	32.19 (0.00)***	8.40 (0.22)	28.15 (0.03)***	8.95 (0.18)	19.19 (0.06)	8.95 (0.18)
Poland	17.16 (0.40)	3.04 (0.87)	14.11 (0.25)	3.04 (0.87)	19.29 (0.26)	3.36 (0.83)	15.93 (0.15)	3.36 (0.83)
Romania	7.21 (0.99)	2.54 (0.93)	4.66 (0.00)	2.54 (0.93)	6.06 (0.99)	2.73 (0.91)	3.33 (0.99)	2.73 (0.91)
Turkey	15.83 (0.51)	2.72 (0.91)	13.11 (0.32)	2.72 (0.91)	17.36 (0.39)	4.21 (0.71)	13.16 (0.32)	4.21 (0.71)
Hungary	13.52 (0.69)	2.17 (0.96)	11.36 (0.48)	2.17 (0.96)	15.78 (0.51)	5.39 (0.54)	10.39 (0.58)	5.39 (0.54)