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The exchange rate volatility in the Central and Eastern European Countries

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Abstract. *The present research aims to model the volatility of the currencies from Romania, the Czech Republic, Hungary and Poland in the period 2005-2014, by identifying a robust econometric model, as well as to determine the empirical values of the long term volatility and expected volatility at the end of the analyzed period. The results obtained have confirmed the validity of the GARCH (1,1) model and the unconditional volatility expressed in annual terms is relatively close for all four currencies, respectively between 8% - 10.6%. However, the values expected for the end of 2014 show significant deviations from the long term volatility, with the largest deviation registered in the case of the RON.*

Keywords: volatility, heteroskedasticity, GARCH models, mean reversion.

JEL Classification: C58, F31, G17.

1. Introduction

The onset of the economic and financial crisis represented a major shock for the Central and Eastern European (CEE) countries' economies and generated severe consequences for the main macroeconomic variables. The crisis coincided with the need to adjust some imbalances such as the budgetary imbalance or that of the current account balance, the latter one correction taking place in the context of a significant depreciation of these countries' currencies. These evolutions determined an exchange rate volatility increase, with potential additional negative effects on these countries economic environment.

Modelling the exchange rate volatility represents an important objective for the economic policy makers, but also for the other participants at the economic activity. For example, this influences the degree of achievement regarding the nominal convergence criteria, given that one of them refers to the maximum permissible deviation of the exchange rate within two years of observation. Also, the banking system can be affected in many ways by greater than expected exchange rate volatility, for example, the Value-at-Risk models based on which the minimum capital requirements are determined, use as input estimates of this variable, and further an underestimation of the exchange rate risk can lead to an insufficient level of equity which is essentially a buffer to cover unexpected losses.

Considering the exchange rate data series' properties, respectively the volatility variability in time, it is very important to identity a long term level of it, but also to determine a current value of this indicator in order to be able to anticipate the future evolutions, in the presence of the mean reversion feature.

Given all these, the present research aims to model the exchange rate volatility of the Romanian, Czech, Polish and Hungarian currencies against the Euro, and, implicitly, to determine the long term volatility, if the estimates confirm its existence, and also to calculate the conditional volatility at the end of the period. This paper's contribution to the literature's development will consist in the precise numerical determination of these values, beyond confirming the validity of the model used.

This paper is structured as follows: the next section presents the previous approaches in the literature on exchange rate volatility modeling in CEE countries, followed by the model description, and later the presentation of the data used and the results obtained. The last section exposes the conclusions and the implications of the empirical estimates.

2. Literature review

A feature of the exchange rate series is the volatility variability in time, so it is necessary to use a model that takes into account this aspect. The GARCH models (the Generalized Autoregressive Conditional Heteroskedasticity), introduced by Bollerslev (1986) are used in analyzing financial time series such as stock prices, inflation rates or exchange rates. The importance of these models is the distinction between the conditional and the unconditional variance. The unconditional variance is independent of time, while the conditional variance depends on past events that are contained in the information available at time t-1.

Over time there have been proposed various extensions of the GARCH model – IGARCH (Integrated Generalized Autoregressive Conditional Heteroskedasticity), EGARCH (Exponential General Autoregressive Conditional Heteroskedasticity), GARCH-M (GARCH in Mean) etc., but the empirical studies have showed that the classical GARCH model is suitable for analyzing the exchange rate volatility. Thus, Hansen and Lunde (2005) analyzed the performance of ARCH and GARCH class models in terms of their ability to describe variance. They used the DM-USD exchange rate and the IBM stocks' return in order to compare about 300 variations of GARCH models and showed that the performance of the classical GARCH (1,1) was not exceeded in case of the exchange rate series.

A topic of interest in the literature is represented by the analysis of the exchange rates volatility in the newest members of the European Union, namely the Czech Republic, Hungary, Poland, Slovakia and Romania. Thus, Kocenda and Valachy (2006) have compared the exchange rate volatility under various currencies regimes for the first four countries, utilizing a TGARCH model (threshold GARCH). By estimating the conditional volatility it was showed that an exchange rate regime shift induces a slight volatility increase. Also, the external shocks do not have a uniform impact on different currencies; these differ among countries, the volatility being determined by specific national reasons.

Fidrum and Horvath (2008) have extended the analysis by introducing Romania and have modeled the exchange rates based on GARCH and TGARCH models. Their main conclusion was the volatility persistence in the case of all five currencies during the period January 1999–May 2007; the chosen interval was determined by the Euro introduction. Also, the authors have noted that none of the five currencies have experienced currency crisis in the analyzed period. At the same time, the exchange rate is more volatile if it is further from the implicitly target rate, which suggest the existence of variation corridors in some of these countries, but which suffer from lack of credibility.

Trenca and Cociuba (2011) investigated the EUR/RON exchange rate evolution in the period 2005-2011 based on three models GARCH, TGARCH and GARCH-M. They found a distinct evolution on two intervals: during 2005-2007 the Romanian RON continuously appreciated, respectively 2007-2011 when the currency was characterized by depreciation and when the volatility was slightly superior to the one from the previous period, reaching a maximum level during the financial crisis, i.e. 2008-2009. As a result of the analysis performed, the authors have shown the suitability of using GARCH models to characterize the exchange rate because of the properties presented by this financial series – serial correlation, non-stationary, heteroskedasticity etc.

The EUR/RON exchange rate volatility was analyzed also by Begu, Spătaru and Marin (2012) through GARCH and EGARCH. In the period January 2009–October 2012, the daily conditional volatility was very persistent, the negative shocks contributed to a variance increase, while the positive ones lead to a variance decrease. Testing various models, they concluded that the GARCH (1,1) adequately describes the EUR / USD exchange rate.

Another way of analyzing the EUR/RON volatility is by comparing it to other currencies' volatility. Thus, Pelinescu (2013), using a database consisting of daily records from the period 05.01.2000-31.08.2012, which was modeled through various GARCH models, found that the Romanian RON behaves differently compared to other currencies, namely the crisis impact on volatility was felt less than in the case of the dollar, zloty and koruna. The shock experienced by the RON was caused to the change of the reference implicit basket (initially, 75% euro and 25% dollar and later 100% euro).

Therefore, we can conclude that the GARCH models are suitable for analyzing exchange rates series, being widely used in empirical analyzes. The contribution of this research is to determine the explicit numerical results for the long-term volatility and for the current expected volatility. The importance of obtaining concrete numerical results is given by the fact that exchange rate volatility is widely used in risk management in the banking system, in order to determine the minimum capital requirements. We will also highlight how much time is needed to correct the volatility deviation from its long time mean in the case of model used.

3. The methodology

For the analysis of the exchange rate volatility we will use a GARCH (1,1) model, proposed by Bollerslev in 1986:

$$\sigma_n^2 = \gamma V_L + \alpha u_{n-1}^2 + \beta \sigma_{n-1}^2 \quad (1)$$

where σ_n^2 represents the expected variance for the next day; V_L is the long term variance and γ is the weight assigned to this; u_{n-1}^2 denotes the squared return of the most recent observation which has a weight equal to α, σ_{n-1}^2 represents the previous variance, weighted with β. Between γ, α and β there is the following relation $\gamma + \alpha + \beta = 1$.

Thus, by specifying the GARCH (1,1) model in the form described above, the current expected variance can be determined based on the most recent observation u_{n-1}^2 and on the latest previous variance σ_{n-1}^2 , the associated weights being econometrically estimated. The more general GARCH (p,q) estimates σ_n^2 based on the most recent p recent return observations, respectively on the last q variances, but the most widely used specification remains the classical GARCH (1,1).

Denoting $\omega = \gamma V_L$, the relation (1) can also be written as follows:

$$\sigma_n^2 = \omega + \alpha u_{n-1}^2 + \beta \sigma_{n-1}^2 \quad (2)$$

this being the form used for estimating the parameters. After estimating the parameters ω, α and β, the long term variance can be calculated:

$$V_L = \frac{\omega}{1-\alpha-\beta} \quad (3)$$

In order to have a stable GARCH (1,1) it is necessary to $\alpha + \beta < 1$; otherwise the weight assigned to the long term variance (γ) would be negative.

If the GARCH model is stable, the variance tends to its long time value (V_L), which is known in the literature as mean reversion. If the parameter ω is equal to zero, the above mentioned phenomenon does not characterize the series, so it is not appropriate to use a GARCH model. An alternative would be the use of an EWMA model (Exponentially Weighted Moving Average), which is, in fact, a particular case of the GARCH model, having the following parameters $\gamma = 0$, $\alpha = 1 - \lambda$ and $\beta = \lambda$.

In order to estimate the parameters, we will use the maximum likelihood method, assuming that the daily returns follow a normal distribution with the mean equal 0 and variance *v*. Considering the probability density function for the normal distribution:

$$f(x) = \frac{1}{\sqrt{2v}} \exp\left(\frac{-u_i^2}{2v}\right) \quad (4)$$

the likelihood of m observations occurring in the order in which they are observed is:

$$L = \prod_{i=1}^{m} \left[\frac{1}{\sqrt{2\pi v}} \exp\left(\frac{-u_i^2}{2v}\right)\right] \quad (5)$$

Using the maximum likelihood method, the best estimate for the variance *v* is the value that maximizes equation (4).

Maximizing an expression is equivalent cu maximizing the logarithm of the expression.

$$\ln L = \sum_{i=1}^{m} \left[- \ln v - \frac{-u_i^2}{v}\right] \quad (6)$$

or equivalent:

$$\ln L = -mln(v) - \sum_{i=1}^{m} \frac{-u_i^2}{v} \quad (7)$$

We will estimate the parameters ω, α and β so that the sum obtained through relation (6) or (7) is maximized, which implies using an iterative algorithm.

At the same time, based on the estimated parameters and the long time variance thus determined, we can calculate the expected variance after t days based on the following formula:

$$E[\sigma_{n+t}^2] = V_L + (\alpha + \beta)^t (\sigma_n^2 - V_L) \quad (8)$$

where $E[\sigma_{n+t}^2]$ represents the expected variance after t days.

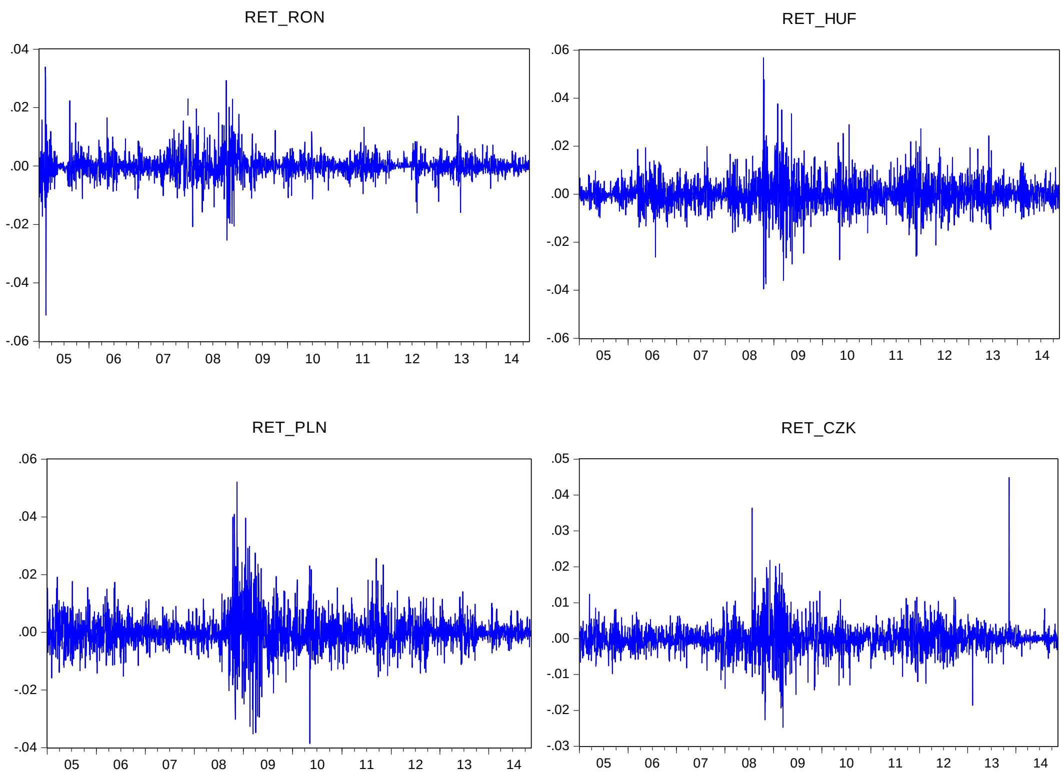
4. Data and empirical results

In the empirical analysis, we have used the exchange rate against the euro of the currencies from Romania, the Czech Republic, Hungary and Poland, respectively the following currency pairs: EUR/RON, EUR/CZK, EUR/HUF, EUR/CZK, for the period 01/03/2005-11/12/2014. The database has consisted of 2510 daily registrations, obtained from the National Bank of Romania's website, which were processed to logarithmic returns, as required by the model, based on the formula:

$$ret\_X = \ln\left(\frac{X_t}{X_{t-1}}\right) \tag{9}$$

where X is the name of the initial series, respectively the exchange rate series.

Graph 1. *The exchange rate returns evolution*



Source: NBR, own calculations.

The statistical analysis confirms the presence of heteroskedasticity, and also the volatility clusters in the considered series, as it can be observed in the above graphics.

Table 1. *Descriptive statistics:*

	Ret_RON	Ret_HUF	Ret_PLN	Ret_CZK
Mean	4.78E-05	8.98E-05	1.37E-05	-3.74E-05
Median	-0.000112	-9.25E-05	-0.000249	-6.73E-05
Maximum	0.033856	0.056795	0.052089	0.044883
Minimum	-0.051064	-0.039443	-0.038604	-0.024748
Std. Dev.	0.004238	0.006665	0.006341	0.004115
Skewness	0.037232	0.418044	0.510303	0.751081
Kurtosis	18.6818	9.495183	10.57383	14.90942
Jarque-Bera	25699.11	4481.633	6103.268	15057.48
Probability	0.000000	0.000000	0.000000	0.000000

Source: NBR, own calculations

It can be seen that in all series, the mean tends to 0, which is consistent with the assumptions made by the model. Based on the historical data, the highest volatility was recorded by HUF (a standard deviation of 0.66% - equivalent to an annual volatility of 10.58%), while the standard deviation of CZK had a minimum level among the analyzed currencies, respectively 0.4115%, which corresponds to an annual volatility of 6.53%.

All four series have positive skewness, indicating the presence of heavy tails to the right, respectively a tendency of depreciation registered by the analyzed currencies relative the euro. Also, in practice, if the value of this indicator lies in the interval (-1,1), it can be considered that the analyzed series is not far from the symmetrical distribution, which is the case of the considered series.

Another feature of these series is the excess kurtosis, indicating a higher probability of occurrence of extreme values than that indicated by the normal distribution, the highest value being recorded in the case of the EUR/RON exchange rate return series (18.68). Thus, we could anticipate a greater volatility of the Romanian currency, compared to the others. The minimum value for this indicator is present in the case of the HUF, respectively 9.49, but this is also greater than the one corresponding to the normal distribution.

The Jarque-Bera test confirms the results provided by the other indicators, namely the fact that the distributions of the exchange rates returns analyzed are far from the normal distribution. Thus, the assumption that the data follow a normal distribution is a simplifyng one, and relaxing it could represent a future research direction, for example by using a Student distribution.

Table 2. *The results of applying the GARCH (1,1) model*

	RON	CZK	HUF	PLN
α	0,1715	0,1269	0,0956	0,0855
β	0,8227	0,8564	0,8958	0,9059
ϒ	0,0058	0,0167	0,0086	0,0086
Long term volatility - daily	0,668%	0,506%	0,668%	0,567%
Long term volatility - annual	10,601%	8,039%	10,609%	8,998%

Source: NBR, own calculations.

Through the method of maximum likelihood, based on an iterative algorithm, we estimated the parameters of GARCH (1,1) in the case of the exchange rates returns EUR/RON, EUR/CZK, EUR/HUF and EUR/PLN, according to relation (2). The results obtained are summarized in the table above, α representing the weight associated to the squared return from the previous day, respectively of the last information available, β denoting the weight associated to the previous day variance, while γ is the weight of the long term variance. We note that in the case the EUR/RON exchange rate, the latest observation has the greatest influence on the next day conditional volatility, among the four series considered (the maximum value for the alpha parameter is 0.1715, followed by CZK - 0.1269 and HUF - 0.0956, while in the case of the PLN this value is minimum - 0.0855). Regarding the results obtained for beta, the highest value characterizes the zloty – 0.9059, followed by the forint – 0.8958 and the koruna - 08564, the leu recording the lowest value for this parameter – 0.8227. It can be noted that in the case of all series, the stability condition is verified ($\alpha + \beta < 1$). The weight associated to the long term variance, determined based on the relation $\gamma = 1 - \alpha - \beta$, takes values between 0.0056 and 0.0167, the lowest being in the case of the RON and the highest for the CZK, while those determined for PLN and HUF registered approximately the same values for this parameter, respectively 0.0086.

Based on the estimated parameters, α, β and ω, we have determined the long time variance according to equation (3), the volatility being calculated as the variance squared root. It should be noted that the results returned by the algorithm are daily, and in order to determine the annual volatility we have to apply the following transformation:

$$Annual\ volatility = Daily\ volatility * \sqrt{252} \qquad (10)$$

It is found that the highest long time volatility is recorded in the case of the EUR/HUF exchange rate volatility (10.609%), a close value characterizing the EUR/RON exchange rate (10,601%), followed by the PLN, approximately 9%. Among the analyzed currencies, the less volatile is the CZK, approximately 8%.

Another point of interest is the determination of the conditional volatility, expected in the following day. Thus, the maximum value appears in the case of the EUR/PLN exchange rate, the expected daily volatility being equal to 0.642% - the equivalent annual volatility is 10.19%, followed by the HUF – a daily volatility of 0.335% and annual of 5.31%, CZK – daily volatility 0.318% and annual of 5.04% and RON – daily volatility of 0.713% and annual of 2.75%. It should be noted that in the case of the leu, the expected volatility is the most remote from the long time volatility, among the analyzed series, the difference, expressed in annual terms, being equal to 7.85 pp. The smallest difference between the conditional and the unconditional volatility is registered in the case of the CZK, respectively 3 pp. In the case of the PLN, the conditional expected volatility is larger than the long time volatility with about 1.91 pp., while for the other currencies, the conditional volatility is smaller than its long time value.

Based on the estimated parameters and the long time variance, we have determined, according to equation (9), the time interval in which the spread between the conditional and unconditional volatility will be reduced to half. As expected, the deviation from the long time variance will correct in the longest period in the case of the EUR/RON exchange rate, as the difference between the unconditional and the conditional variance will halve in about 118 days, while for the EUR/CZK, the deviation will correct in the shortest time, respectively in about 41 days. For the other two currencies, the difference between the long time variance and the current one will be reduced to half in about 80 days.

5. Conclusions

The present research has aimed to model the volatility of the currencies from Romania, the Czech Republic, Hungary and Poland, given the presence of heteroskedasticity in the series or more concrete to determine numerically the long time variance and current variance based on estimating a robust econometric model. The results have confirmed the validity of the GARCH (1,1) model for all the analyzed currencies, and the values obtained for the long time variance, belong to the interval 8% and 10.6%. These values are compatible with the nominal converge criteria related to the exchange rate which allows $\pm$15% fluctuations from the central parity for a period of at least two years of participation in the ERM Mechanism, but the proper choice of the initial level should not be ignored.

Also, the current volatility is above the long time average only for the zloty, while the leu, the forint and the Czech crown have significantly lower expected volatilities than the long time level, the biggest difference being recorded in the case of the RON. Thus, it is expected a volatility increase in the case of the leu, forint and Czech crown, with major implications on the capital requirements calculated by the banks to cover the exchange rate risks. Also, it should not be ignored the effect that a volatility increase could have on the debtors in foreign currencies unhedged to exchange rate risks, as well as the additional uncertainties that would accompany such an evolution.

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