7. The Analysis of the Dynamic Relationships between Real Exchange Rates and Macroeconomic Variables in Selected Countries with Targeted Inflation: Evidence from Linear and Non-Linear ARDL Models

Đorđe ĐUKIĆ[1]
Mustafa ÖZER[2]
Mališa ĐUKIĆ[3]

Abstract

The paper uses linear and non-linear autoregressive distributed lag (ARDL and NARDL) models to examine the short-and long-term impacts of real effective exchange rate (REER) on industrial production, exports and imports in Hungary, Poland, Romania and Serbia over the period of 2000Q1–2022Q4. Also, we carry out Granger causality tests as a robustness checking of ARDL and NARDL results. Finally, we conduct a volatility analysis of REER based on the estimates of the GARCH and EGARCH models. The results of bounds tests of ARDL and NARDL indicate the existence of linear and nonlinear cointegrations between industrial production and selected macroeconomic variables. Short-run and long-run Granger causality test results do support the results of ARDL and NARDL models. It is of exceptional importance for the policymakers to observe the influence of REER volatility on industrial production and exports after the onset of the global financial crisis, by comparing the average values of volatility and the inter-annual growth rates of the mentioned aggregates. REER and its volatility is one of the key variables in sample countries to affect the industrial production, exports and imports. Policies aiming to influence these variables should take into account dynamic relations between REER and other variables. The results show that the long-term application of free-floating exchange rate (case of Poland with high REER volatility) is adequate in terms of providing an incentive for export and industry growth. When applying managed floating and floating exchange rate (Hungary, Romania and Serbia) the impact of REER volatility depends on case-by-case basis especially after the outbreak of the global financial crisis. High REER volatility in Hungary did not have a negative

[1] *University of Belgrade, Faculty of Economics, Kamenička 6, 11000 Belgrade, Serbia. Email:profdjdjukic@gmail.com*

[2] *Anadolu Üniversitesi: Eskisehir, 26470 Tepebaşı/Eskişehir, Turkey. Email:muozer@anadolu.edu.tr*

[3] *Corresponding Author. Belgrade Banking Academy – Faculty of banking, finance and insurance, Zmaj Jovina 12, 11000 Belgrade, Serbia. Email:djukicmalisa@hotmail.com*

impact on the growth of its exports and industrial production. Low REER volatility in Serbia and Romania was followed by lowest growth rates of industrial production in Serbia while it was not the case in Romania.

Keyword: Exchange rate, production, exports, targeted inflation, ARDL

JEL Classification: C22, E52, F14, F31, G01

1. Introduction

Since 2000, there have been two groups of studies focused on analysing the influence of the REER on the economic activity in developing countries or emerging market economies (EME). In the first group the influence of the REER on economic growth is quantified mostly in terms of the GDP per capita. In the second group the link between the REER and imports and exports in a selected group of countries with different or similar exchange rate regimes is most frequently analysed. Our focus is on the second group of studies. The results of the evaluation of the influence of the REER on exports and imports vary from country to country and depend on the chosen model. They mainly refer to Asian EME and were reached, among other things, by means of the autoregressive distributed lag (ARDL) model. A combination of the ARDL Bounds testing cointegration approach and generalized autoregressive conditional heteroskedasticity (GARCH) models was used only by Alam & Qazi (2012).

This paper includes four EMEs from Europe with targeted inflation which, after the onset of the global financial crisis (GFC), implemented, according to the International Monetary Fund's (IMF's) classification one of two variants of the de facto floating exchange rate regime – Hungary, Poland, Romania and Serbia. For the first time a combination of the ARDL Bounds testing approach and GARCH models will be used to examine the link between the REER and industrial production, exports and imports in those countries. We first examine the time series properties of variables i.e., degree of integration of variables. Secondly, we continue with testing the presence of cointegration among variables, and finally we test the short-term and long-term causalities by using Granger causality tests. Also, by using GARCH or EGARCH models, we try to model the volatilities of REER for each country and observe its effects on other variables.

The main findings are as follows. First, there are evidences of long-term relationships among the REER, industrial production, exports and imports in the four countries. Secondly, short-term and long-term Granger causality tests support the view that REER is one of the key factors affecting the industrial production, exports and imports. Thirdly, the highest volatility of REER in Poland was not an obstacle for good export performances of the Polish economy after GFC.

Emerging market economies with different exchange rate regimes (currency board arrangements and fixed exchange rates) cannot be compared with the aforementioned countries, and were thus not included in this analysis.

In our paper we intend to answer the following research questions. Is there a long-term relationship between the REER and industrial production? Is there a short-term and/or long-term relationship between the REER and real exports/imports? Does the selected exchange rate regime have a significant impact on industrial production and real exports/imports?

The first contribution of the paper is that we present short-and long-run effects together. The second contribution is that we provide evidences of causal relations among the variables. Finally, we estimate the volatility of exchange rate so that one can easily see the effects of exchange rate regime on the exchange rate.

The next part provides the literature review. The goals of the analysis are described in the second, and methodology and data in the third part. The results are presented in the fourth part and the conclusions in the fifth.

2. Literature Review

Starting from the model which was used in the evaluation of the REER's influence on the real sector of the economy we grouped the studies into those in which ARDL and GARCH models were not used and those in which one of those two models was used.

2.1 Studies which were not based on the ARDL and GARCH models

Using the baseline panel regression, Rodrik (2008) determined that the connection between the REER and economic growth per capita was particularly pronounced in developing countries. According to his evidence, the undervaluation of the currency affects the share of tradables in the economy. Developing countries accomplish faster growth if they increase profitability of tradables. (Rodrik, 2008, p. 370). The results imply that a 50 percent undervaluation is related to an annual increase of real income per capita of 1.3 percentage points (Rodrik, 2008, p. 374).

According to the findings of Rapetti, Skott & Razmi (2011), based on the model used by Rodrik (2008), a competitive real exchange rate is positively correlated with higher economic growth. There are two possible explanations for that. Firstly, an undervalued exchange rate has a stimulative effect on the re-allocation of resources in the direction of tradable sector (Rapetti, Skott, Razmi, 2011, p. 4). Secondly, they emphasize the role of a competitive real exchange rate on loosening foreign exchange bottlenecks as a limiting factor of economic growth. Thus, the positive effect of currency undervaluation has a tendency to decrease with the level of GDP per capita. This is contrary to Rodrik's findings. Their results suggest that the effect of undervaluation on growth appears sizable for middle-income countries, and not only for poor countries (Rapetti, Skott, Razmi, 2011, p. 8).

According to the results gained by Habib, Mileva & Stracca (2016), real depreciation (appreciation) significantly increases (decreases) annual GDP growth per capita. However, that applies only to developing countries with fixed exchange rates (pegs) and is substantially less for advanced countries. They confirmed and strengthened Rodrik's (2008) conclusion. With regards to policy implications they concluded that it is unclear what type of exchange rate regime a developing country should implement in order to promote growth. (Habib, Mileva & Stracca, 2016, p. 17).

Starting from our research goal, we will focus our attention on the most recent studies which examine the influence of the REER on industrial production, exports and imports by implementing different econometric tools. The direct influence on industrial production is not covered by recent studies. Because of the existence of the feedback loop between imports and exports on one side, and exchange rates on the other, the explanation for their inter-relationship is not a simple one. Using an Engle Granger residual based cointegration technique, Ozturk & Kalyoncu (2009) examined the impact of exchange rate volatility on trade flows. The analysis included six countries over 1980–2005 period. They found that increasing volatility of the REER exerts significant both negative and positive effects on trade in the long run (Ozturk & Kalyoncu, 2009, p. 499).

Using panel cointegration techniques and annual data for the 1985-2012 period, Genc & Artar (2014) found that in the long run there was a co-integrated relationship between the REER (effective exchange rate index) and exports-imports in the selected group of 25 emerging countries. In addition, for five countries (Bolivia, Cameroon, Dominica, Gabon and Mexico) the short-term parameters are also statistically significant.

Based on the de facto exchange rate regimes in the selected 12 emerging Asian economies for the 1999–2009 period, Rajan (2012) analysed the impact of real exchange rate devaluation on the sectoral reallocation of resources. He concluded that real exchange rate undervaluation could rapidly boost East Asian economies (Rajan, 2012, p. 65). Four out of twelve countries that were included in the sample implemented inflation targeting.

According to Berthou (2008), the reaction of exports to exchange rate changes varies depending of the nature of the country to which exports are destined. He implemented the Hausman test for the estimation of the gravity equation and the Poisson Pseudo Maximum Likelihood (PPML) estimator, using data for 27 industries including 20 OECD exporters and 52 importing countries (developed and developing) during the 1989-2004 period. His findings confirm that a real (bilateral) exchange rate appreciation reduces the value of bilateral exports. When the importer is an OECD country, the elasticity is higher as opposed to the case when the importer is a developing country. (Berthou, 2008, p. 39)

By using cointegration techniques and ERC (Error Correction Models), Hassan, Chakraborty, Sultana & Rahman (2016) showed that although the REER in Bangladesh had a significant long-term impact on exports, this influence is not statistically significant in the short term (Hassan, et al. 2016, p. 11). REER appreciation had a negative influence on real export earnings in the long run. In the case of Pakistan, using cointegration techniques and monthly data (December 1981-January 2003), Kemal & Qadir (2005) confirmed the existence of long-term dependence between the REER and exports and imports. This connection proved to be negative in the case of exports and positive in that of imports. In contrast to imports, exports did not react to the sudden shock in the real exchange rate. On this basis they concluded "that devaluation might be helpful in improving the trade balance" (Kemal & Qadir, 2005, p. 193). Consequently, there are strong long-term linkages between imports and exports (correlation of 0.96).

Lanau (2017) used panel difference-in-difference methodology to test the effects of real exchange rate depreciation on growth across sectors in Latin American countries (Argentina, Brazil, Chile, Colombia, Costa Rica, and Mexico). The results show that sectors that export more grow relatively faster due to depreciation.

Following the model of Rodrik (2008), Cizmović, Shachmurove & Vulanovic (2021) examined the impact of the REER on the industry value-added share in GDP. The analysis included 25 Eastern European countries, for the period from 1995 to 2018. The 25 countries included Hungary, Poland, Romania and Serbia. By applying heterogeneous panel common factor approach they concluded there is a significant negative relationship between currency strengthening and industrial production (Cizmović, Shachmurove & Vulanovic, 2021, p. 863). According to their paper increases in the REER result in deindustrialisation on average, while negative effect of appreciation is less pronounced in countries with the higher economic complexity index and broader participation of their industries in global value chains.

Bošnjak, Kordić & Novak, (2021) examined the relationship between REER and industry production in Croatia based on monthly data from January 2000 up to June 2019. They applied wavelet coherence analysis with conventional correlation analysis. The empirical findings suggested positive relationship between industrial productivity and REER in Croatia, with depreciation as a factor of positive influence on industrial productivity (Bošnjak, Kordić & Novak, 2021, p. 30). The paper explains limits of depreciation of national currency for improving price competitiveness of Croatian industry: past hyperinflation and high levels of unofficial euroization.

On the basis of statistical data analysis, Twarowska (2015) indicated the relatively high degree of volatility of the NEER and REER of the Polish zloty against the euro in the 2004-2013 period. Consequently, Poland was able to avoid a large drop in exports and GDP during the financial and economic crisis (Twarowska, 2015, p. 54). During the implementation of a free-floating exchange rate regime in Poland, the zloty depreciation resulted in a growth in exports and a decline in the value of imports. The final outcome was the improvement of Poland's trade balance and the conclusion that the fast adoption of the euro was not necessary for Poland. For the selection of the optimal exchange rate regime in EME, the experience of Poland was particularly interesting because out of the four countries with targeted inflation included in this paper – Hungary, Romania, Poland and Serbia, Poland was the only one which transferred to the free-floating regime in 2000. This was after the implementation of the crawling peg, and before the fixed exchange rate regime.

2.2 Papers based on ARDL and GARCH models

A literature review of those studies which refer to the effects of exchange rate (NEER and REER) volatility on trade between 1984 and 2005 was provided by Ozturk (2006, p. 88-92). The most frequently used estimation techniques were OLS, then GARCH and ARCH (five times) followed by Cointegration and VAR (four times).

In their literature review pertaining to the relationship between exchange rates and international trade, in the part dealing with the effects of exchange rate volatility on trade, Auboin & Ruta (2011) stated exchange rate volatility has a negative impact on trade flows on average. The extent of this effect is influenced by a number of factors such as the structure of production and the degree of economic integration across countries.

The relationship of the exchange rate with the exports and imports of major South-Asian Countries and Southeast Asian Countries over the 1979-2010 period was examined by Chaudhary, Hashmi & Khan (2016). Those countries had implemented a flexible/managed exchange rate regime since the late 70’s or early 80’s. Using the ARDL approach to cointegration and ECM they came across two findings. The long run relationship between exchange rate and exports exists in majority of countries including Pakistan, India, Bangladesh, Sri Lanka and Indonesia. However, the significant short run relationship between the mentioned variables does not exist in most of the sample countries. Hence, it was not the REER that was used, but the NEER against the USD, while the exports and imports were given in the national currencies of the sample countries. Consequently, the results are not comparable with the findings from the aforementioned studies.

An estimation of the exports demand for Pakistan was carried out by Alam & Qazi (2012). They used an ARDL model for the period 1982Q1-2008Q2 to examine the long as well as the short run impact of REER volatility along with foreign real income, relative price of exports and REER on demand for exports. The standard deviation of GARCH variance was used to measure REER volatility. They conclude that demand for real exports is co-integrated with the REER and REER volatility, as well as with real foreign income and the relative price of aggregate exports. The volatility of the REER has adversely affected Pakistan’s aggregate exports in the long run.

Sugiharti, Esquivias & Setyorani (2020) analysed the impact of REER volatility on Indonesia’s export to China, India, South Korea, Japan, and the USA from 2006 to 2018 using GARCH and ARDL models. They concluded that exports were positively related with industrial production for China, India, and South Korea, while it was not the case for US and Japan.

3. Goals analysis

The major goal of this study is to establish whether there is link between the REER and the selected economic activity indexes of four countries with targeted inflation: Hungary, Romania, Poland and Serbia. For this goal, we try to provide evidences for the following research questions:

1. Is there a long-term relationship between the REER and industrial production?
2. Is there a short-term and/or long-term relationship between the REER and real exports/imports?
3. Does the selected exchange rate regime - managed floating and floating (in the cases of Hungary, Romania and Serbia) and free floating (in the case of Poland) have a significant impact on industrial production and real exports/imports?

The four countries are selected as they implement the same monetary policy, inflation targeting, which assumes the application of floating exchange rate regime. Given such criteria the four countries are a homogenous group and results of quantitative analysis are comparable and useful for economic policy decision makers. There are CEE countries that do not use inflation targeting and do not implement floating exchange rate regime.

It is necessary to establish the differences in the REER's volatility in the four countries. After that it may be concluded which de facto exchange rate regime with inflation targeting, viewed in the long-term, contributed most to boosting export growth, and in turn industrial production.

4. Methodology and Data

4.1 Empirical Method

To examine the dynamic connections between REER and selected macroeconomic variables, we employ an empirical strategy which consists of two main parts. In the first part of our empirical work, we adopted three stages method. In the first stage, we try to determine the degree of integration of variables by using traditional as well as structural break unit root tests[4]. After establishing that all variable are not integrated of order two and they have a degrees of integration like I(1) and I(0), in the second stage, we carry out linear and nonlinear cointegration tests within the framework of ARDL and NARDL Bounds testing approach. Finally, we carry out Granger causality tests within the VECM framework as a robustness checking of ARDL and NARDL results.

In the second part of our empirical analysis, we estimate GARCH and EGARCH models to obtain the volatilities of REER and use these volatilities to examine their effects on exports, imports and industrial production.

As is indicated in Arize (2017) and other studies, there are some advantages of ARDL modelling. Also, as is argued by Batten, Ciner and Lucey (2010) Özer et al. (2020); Zhou (2020); Brownlees (2010) and Dyhrberg, 2016), the use of GARCH(1,1) model is one of the common practices to obtain the volatilities of any variable.

4.1.1. ARDL and NARDL models

As we indicated above, our main empirical analysis uses ARDL proposed by Pesaran & Shin (2013) and Pesaran, Shin & Smith (2001) and NARDL proposed by Shin et al. (2014). The main advantages of using ARDL framework to investigate the existence of cointegration among variables are as follows:

- It is easier to use because after testing for the existence of long run cointegrating interdependencies and establishing the number of lags which will be used in the model, the same can be evaluated by means of the OLS model.
- While Johansen's approach depends to a great extent on whether we have correctly established the order of integration, i.e. the existence of a unit root, the approach by means of the ARDL model does not demand the previous establishment of the order of integration. Moreover, this approach allows the inclusion of a series with different order of integration, i.e. series I(0) and I(1) even in the case when the included series are not cointegrated.
- Johansen's approach is based on the use of the VAR model with at least two equations and a larger number of coefficients which have to be estimated. The ARDL approach is a single equation model with a significantly smaller number of coefficients for estimation. This

[4] *We didn't include the results of these tests to save the space. But they are obviously available upon request.*

characteristic of the ARDL approach is particularly important when there is a relatively short series as was the case in this analysis of quarterly time series.

In the ARDL F-Bounds Test for cointegration, the estimated value of the F-statistic is compared with two sets of critical values, with upper and lower bounds. If the F-statistic is higher than the upper bound, the null hypothesis of no cointegration is rejected. If the value of the F-statistic is between the upper and lower bounds, the decision cannot be made. If the value of the F-statistic is lower than the lower bound, then the null hypothesis of no cointegration cannot be rejected. We use following equations to carry out cointegration tests by using ARDL Bounds testing approach:

First equation for each dependent variable is ARDL(m,n,l,p); second equation is test equation and third one is unconstrained error correction model.

$$LEXP_t = \Theta_0 + \sum_{i=1}^{m} \Theta_{1i} LEXP_{t-i} + \sum_{i=0}^{n} \Theta_{2i} LIMP_{t-i} + \sum_{i=0}^{l} \Theta_{3i} LIND_{t-i} + \sum_{i=0}^{p} \Theta_{4i} LREER_{t-i} + e_t \quad (1a)$$

$$\Delta LEXP_t = \theta_0 + \sum_{i=1}^{m} \theta_{1i} \Delta LEXP_{t-i} + \sum_{i=0}^{n} \theta_{2i} \Delta LIMP_{t-i} + \sum_{i=0}^{l} \theta_{3i} \Delta LIND_{t-i} + \sum_{i=0}^{l} \theta_{4i} \Delta LREER_{t-i} + \theta_5 LEXP_{t-i} + \theta_6 LIMP_{t-i} + \theta_7 LIND_{t-1} + \theta_8 LREER_{t-1} + e_{1t} \quad \text{(1b)}$$

The null and alternative hypotheses are stated as following:

H_0: $\theta_5 = \theta_6 = \theta_7 = \theta_8 = 0$, *$H_1$: At least one $\theta \neq 0$*

$$\Delta LEXP_t = \theta_0 + \sum_{i=1}^{m} \theta_{1i} \Delta LEXP_{t-i} + \sum_{i=0}^{n} \theta_{2i} \Delta LIMP_{t-i} + \sum_{i=0}^{l} \theta_{3i} \Delta LIND_{t-i} + \sum_{i=0}^{p} \theta_{4i} \Delta LREER_{t-i} + \theta_5 ECM_{t-1} + e_{2t} \quad (1c)$$

$$LIMP_t = \beta_0 + \sum_{i=1}^{m} \beta_{1i} LIMP_{t-i} + \sum_{i=0}^{n} \beta_{2i} LEXP_{t-i} + \sum_{i=0}^{l} \beta_{3i} LIND_{t-i} + \sum_{i=0}^{l} \beta_{4i} LREER_{t-i} + \varepsilon_t \qquad \text{(2a)}$$

$$\Delta LIMP_t = \beta_0 + \sum_{i=1}^{m} \beta_{1i} \Delta LIMP_{t-i} + \sum_{i=0}^{n} \beta_{2i} \Delta LEXP_{t-i} + \sum_{i=0}^{l} \beta_{3i} \Delta LIND_{t-i} + \sum_{i=0}^{l} \beta_{4i} \Delta LREER_{t-i} + \beta_5 LIMP_{t-i} + \beta_6 LEXP_{t-i} + \beta_7 LIND_{t-1} + \beta_8 LREER_{t-1} + \varepsilon_{1t} \quad (2b)$$

H_0 : $\beta_5 = \beta_6 = \beta_7 = \beta_8 = 0$, H_1: At least one $\beta \neq 0$

$$\Delta LIMP_t = \beta_0 + \sum_{i=1}^{m} \beta_{1i} \Delta LIMP_{t-i} + \sum_{i=0}^{n} \beta_{2i} \Delta LEXP_{t-i} + \sum_{i=0}^{l} \beta_{3i} \Delta LIND_{t-i} + \sum_{i=0}^{l} \beta_{4i} \Delta LREER_{t-i} + \beta_5 ECM_{t-1} + \varepsilon_{2t} \quad (2c)$$

$$LIND_t = \delta\Theta_0 + \sum_{i=1}^{m} \delta_{1i} LINP_{t-i} + \sum_{i=0}^{n} \delta_{2i} LEXP_{t-i} + \sum_{i=0}^{l} \delta_{3i} LIMP_{t-i} + \sum_{i=0}^{l} \delta_{4i} LREER_{t-i} + w_t \quad (3a)$$

$$\Delta LIND_t = \delta_0 + \sum_{i=1}^{m} \delta_{1i} \Delta LIND_{t-i} + \sum_{i=0}^{n} \delta_{2i} \Delta LEXP_{t-i} + \sum_{i=0}^{l} \delta_{3i} \Delta LIMP_{t-i} + \sum_{i=0}^{l} \delta_{4i} \Delta LREER_{t-i} + \delta_5 LIND_{t-i} + \delta_6 LEXP_{t-i} + \delta_7 LIMP_{t-1} + \delta_8 LREER_{t-1} + +w_{1t} \quad (3b)$$

H_0 : $\delta_5 = \delta_6 = \delta_7 = \delta_8 = 0$, H_1: At least one $\delta \neq 0$

$$LIND_t = \delta_0 + \sum_{i=1}^{m} \delta_{1i} \Delta LIND_{t-i} + \sum_{i=0}^{n} \delta_{2i} \Delta LEXP_{t-i} + \sum_{i=0}^{l} \delta_{3i} \Delta LIMP_{t-i} + \sum_{i=0}^{l} \delta_{4i} \Delta LREER_{t-i} + \delta_5 ECM_{t-1} + w_{2t} \quad (3c)$$

To implement the nonlinear cointegration (asymmetric cointegration), we use NARDL framework. To do this, we first decompose the NARDL model and decompose the changes in any variable into two parts to analyse the different impacts of positive and negative changes in that variable on dependent variable. Therefore, the positive and negative changes (shocks) in related variable are expressed as follows:

$$X_t^+ = \sum_{J=1}^{t} \Delta X_j^+ = \sum_{J=1}^{t} max(\Delta X_j, 0)$$

$$X_t^- = \sum_{J=1}^{t} \Delta X_j^- = \sum_{J=1}^{t} min(\Delta X_j, 0)$$

Where

$X_t = X_t^+ + X_t^-.$

When we use the negative and positive changes in any variable, we can write ARDL equation between X and Y as;

$$\Delta Y_t = \alpha_0 + \delta_1 Y_{t-1} + \delta_1 X_{t-1}^+ + \delta_2 X_{t-1}^- + \sum_{i=1}^{r} \beta_i \Delta Y_{t-i} + \sum_{i=0}^{s} (\gamma_i^+ \Delta Y_{t-i}^+ + \gamma_i^- \Delta Y_{t-i}^-) + \varepsilon_t$$

Based on the above equation, one can compute the long-run effects of positive and negative changes in X on Y as$-\frac{\delta_2^+}{\delta_1}$ and $-\frac{\delta_2^-}{\delta_1}$ respectively.

To test the existence of asymmetric cointegration between X and Y, we test the null hypothesis of $H_0: \delta_1 = \delta_2^+ = \delta_2^- = 0$ or $H_0: \delta_1 = 0$.

First null hypothesis is tested by using F_{PSS}; second one is tested by using t_{BDM}, approaches. By carrying out the Wald tests, we can test the presence of short- run or long-run and/or both asymmetric effects of X on Y. The null hypothesis of test of long-run asymmetric effect of X on Y is given by $H_0 = -\frac{\delta_2^+}{\delta_1} = -\frac{\delta_2^-}{\delta_1}$. To test the significance of short-run asymmetric effect of X on Y can also be examined by testing the null hypothesis of $H_0: \sum_{i=0}^{s} \gamma_i^+ = \sum_{i=o}^{s} \gamma_i^-$. Finally, we examine the dynamic multipliers of asymmetric effects.

4.1.2. GARCH model

One of common methods used to model conditional volatilities is to use GARCH models. The following definition of the GARCH model is according to Tsay (2010).

If the given series yields r_t in the time period t, then the innovation series is $a_t = r_t - \mu_t$. We say that a_t follows the GARCH (p, q) model if

$a_t = \sigma_t \epsilon_t, \qquad \sigma_t^2 = \alpha_0 + \sum_{i=1}^{p} \alpha_i a_{t-i}^2 + \sum_{j=1}^{q} \beta_j \sigma_{t-j}^2$

where $\{\epsilon_t\}$ is the series of independent, identically distributed random variables with mean 0 and variance 1, $\alpha_0 > 0$, $\alpha_j \geq 0, \beta_j \geq 0$ and where $\sum_{i=1}^{\max(p,q)} (\alpha_i + \beta_i) < 1$. For $i > p$ is $\alpha_i = 0$, while for $j > q$ is $\beta_j = 0$. The constraint on $\alpha_i + \beta_i$ results in the unconditional variance of innovation a_t final, while the conditional variance σ_t^2 varies over time. It is assumed that ϵ_t has standard Student's *t*-distribution or Generalized error distribution (GED). The coefficients α_j and β_j are named the ARCH and GARCH coefficients.

The four steps involved in estimating the GARCH model are as follows:

1. The mean value equation for the yield series (the ARMA model for instance) is estimated if the testing shows the existence of serial dependence in the yields.
2. The mean value equation for the yield series residuals is used to test for the existence of the ARCH effect.

3. If the ARCH effects are statistically significant, the volatility model is specified and the equations of the mean values and volatility are estimated together.
4. Finally, the adequacy of the obtained model is tested and changes are made if required.

There are numerous extensions of the GARCH model. We used the EGARCH when the GARCH model did not provide satisfactory results.

3.2 Data

The estimation of the ARDL model was carried out on the basis of quarterly time series in the period 2000Q1–2022Q4, and that of the GARCH model on the monthly series in that period. The choice of periods was dictated by the fact that there are comparable data for all four countries. In the case of Serbia, because of the events during the 1990's (hyperinflation, years of sanctions) the series in the period prior to the year 2000 showed 'nonstandard' behaviour in comparison with the period before and after those events. For the REER series there was no available data before 2002 for Serbia.

The four countries of Central and Eastern Europe were selected as they implemented inflation targeting and floating exchange rate regime.

While modelling the long run relationship between the sample time series, changes in the exchange rate regime were included. As presented in Table 1, Poland and Romania did not change the exchange rate regime after 2000, and Hungary changed the exchange rate regime just before the GFC – in May 2008. In Serbia, the regime was changed after the onset of the GFC – in January 2009. Therefore, after the GFC, Poland continued to implement free floating, and Romania managed floating and floating, while Hungary and Serbia started to implement managed floating.

Table 1. De facto exchange rate regime in Hungary, Poland, Romania and Serbia

Country	*Period*	*Exchange rate regime*
Hungary	2000/1 – 2008/4 2008/5 – 2022/12	Peg with horizontal bands Managed floating and Floating
Poland	2000/4 - 2022/12	Free Floating
Romania	1998/1 – 2017/12 2018/1- 2022/12	Managed floating and Floating Stabilized arrangement
Serbia	2002/2 – 2008/12 2009/1 – 2015/12 2016/1 – 2022/12	Mixed Fixed and "Dirty floating" Managed floating and Floating Stabilized arrangement

The data description is provided in Appendix A (Table 1). The original data is available upon request. Deseasonalised time series are used in the log form. Two artificial variables were also constructed: first, under the name 'regime' for the goal of quantifying the effects of the exchange rate regime changes which occurred in Hungary and Serbia; second, under the name 'crises' for the goal of quantifying the effects of the GFC.

5. Results

5.1 Estimating the ARDL model

We estimate the three ARDL models for the sample countries over the period from 2000 Q1 to 2022 Q4. The F-Bounds Test results show the existence of a long-term relation between the REER, exports, imports and industrial production in all observed countries (Table 2).

Table 2. Cointegration test results

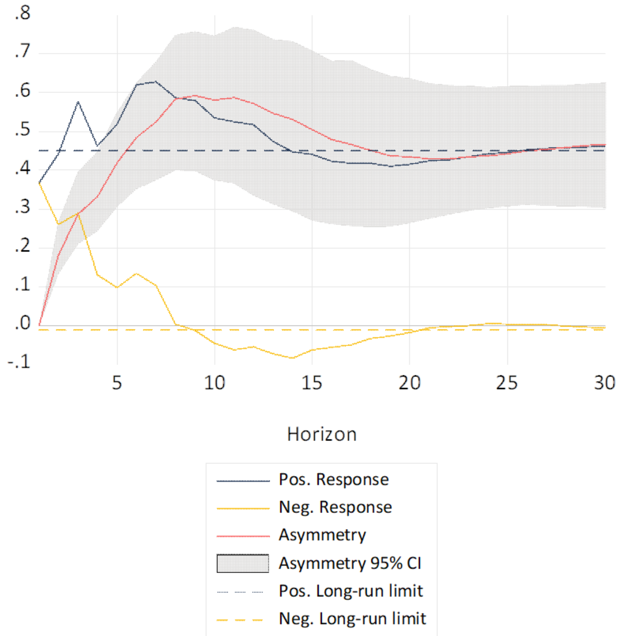
Estimated Models	*F-Statistic*	*Significance level*	*Bound critical values*		*Conclusion*
			I(0)	*I(1)*	
Panel A: Hungary					
F_{EXP}(EXP/IMP,IND,REER	7.33	1%	3.90	5.04	Cointegration
F_{IMP}(/IMP/EXP,IND,REER)	5.40	1%	3.90	5.04	Cointegration
F_{IND}(IND /IMP,EXP,REER)	9.39	1%	3.90	5.04	Cointegration
Panel B: Poland					
F_{EXP}(EXP/IMP,IND,REER)	4.07	1%	3.91	5.04	Cointegration
F_{IMP}(/IMP/EXP,IND,REER)	8.73	1%	3.90	5.04	Cointegration
F_{IND}(IND /IMP,EXP,REER)	7.46	1%	3.60	4.79	Cointegration
Panel C: Romania					
F_{EXP}(EXP/IMP,IND,REER)	6.74	1%	3.60	4.79	Cointegration
F_{IMP}(/IMP/EXP,IND,REER)	4.97	1%	3.65	4.66	Cointegration
F_{IND}(IND /IMP,EXP,REER)	4.91	1%	3.65	4.66	Cointegration
Panel D: Serbia					
F_{EXP}(EXP/IMP,IND,REER)	8.15	1%	3.60	4.78	Cointegration
F_{IMP}(/IMP/EXP,IND,REER)	9.31	1%	3.90	5.04	Cointegration
F_{IND}(IND /IMP,EXP,REER)	8.90	1%	4.05	5.09	Cointegration

In the case of Poland (F_{IND}(IND/IMP,EXP,REER)) and Romania FEXP(EXP/IMP,IND,REER) there is no linear cointegration between industrial production and other variables and exports and other variables respectively. Therefore, NARDL was estimated. The results are presented in Table 2. Additional NARDL results are below and include long-run symmetry test results and dynamic multipliers effects.

Table 3. NARDL – Symmetry test results for Poland

Test statistics	*Value*	*p-value*
$\mathbf{W_{LR}}$	24.52	7.33e-07

Figure 1. Cumulative Dynamic Multiplier for Poland: LPOLIMP on LPOLIPI

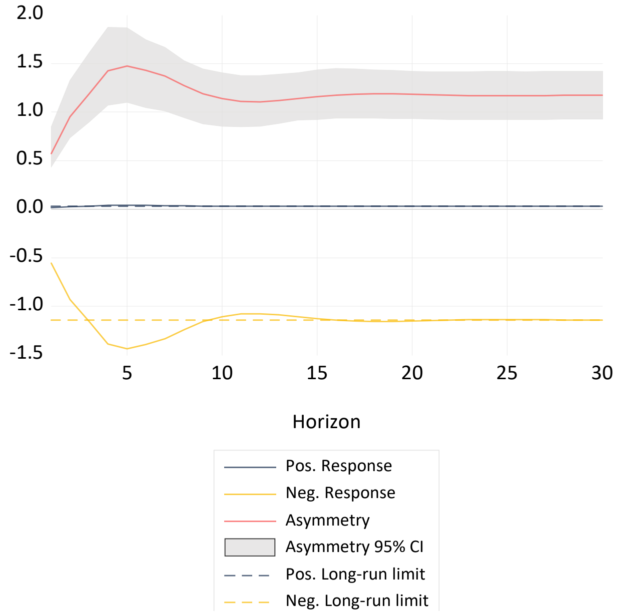


Red line presents the asymmetric effects. Since there is no asymmetry in the short-run, asymmetry is zero in the short-run. But in the long-run it is significant as positive shocks dominate the negative shocks and the multiplier approaches the long-run positive shock value.

Table 4. NARDL – Symmetry test results for Romania

Test statistics	*Value*	*p-value*
W_{LR}	25.47	4.47e-07

Figure 2. Cumulative Dynamic Multiplier for Romania: LROMREER on LROMEXP



Since there is no significant positive REER shocks, the multiplier is zero. But, since the coefficient of negative shock is negative, negative REER shocks are creating positive effects on exports and the multiplier approaches its long-run positive value.

Table 5. Granger causality results

Dependent variables			*Sources of causation*		
		Short-run		*Long-run*	
Panel A: Hungary					
	ΔEXP	ΔIMP	ΔINP	$\Delta REER$	*ECT(-1)*
ΔEXP	-	0.16 (0.2807)	0.4499 (0.3281)	0.01 (0.1845)	-0.23** (0.0805)
ΔIMP	-0.49 (0.3381)	-	0.56* (0.3072)	0.01 (0.1728)	-0.13*** (0.0754)
ΔIND	-0.40 (0.3487)	0.10 (0.2711)	-	0.06 (0.1728)	-0.17*** (0.0777)

Panel B: Poland					
	ΔEXP	ΔIMP	ΔINP	$\Delta REER$	*ECT(-1)*
ΔEXP	-	0.10 (0.2177)	0.31 (0.2062)	0.15 (0.1352)	-0.02*** (0.0561)
ΔIMP	-0.44** (0.2238)	-	0.52*** (0.2058)	0.28** (0.1349)	-0.02*** (0.0056)
ΔIND	-0.20 (0.1634)	0.03 (0.1587)	-	-0.07 (0.0985)	-0.01*** (0.0040)
Panel C: Romania					
	ΔEXP	ΔIMP	ΔINP	$\Delta REER$	ECT(-1)
ΔEXP	-	0.16 (0.1804)	-0.30 (0.2615)	0.09 (0.2870)	-0.03*** (0.0177)
ΔIMP	-0.04 (0.1910)	-	-0.30 (0.2594)	0.25 (0.2847)	-0.0452** (0.0175)
ΔIND	0.00 (0.1304)	0.06 (0.1222)	-	-0.15 (0.1944)	-0.03*** (0.0120)
Panel D: Serbia					
	ΔEXP	ΔIMP	ΔINP	$\Delta REER$	*ECT(-1)*
ΔEXP	-	-0.22 (0.1032)	0.08 (0.2296)	0.16** (0.2633)	-0.45** (0.1151)
ΔIMP	0.25 (0.1974)	-	-0.07 (0.3092)	0.29 (0.3546)	-0.19 (0.1313)
ΔIND	0.08 (0.0918)	-0.07 (0.0646)	-	0.37** (0.1649)	-0.34*** (0.1324)

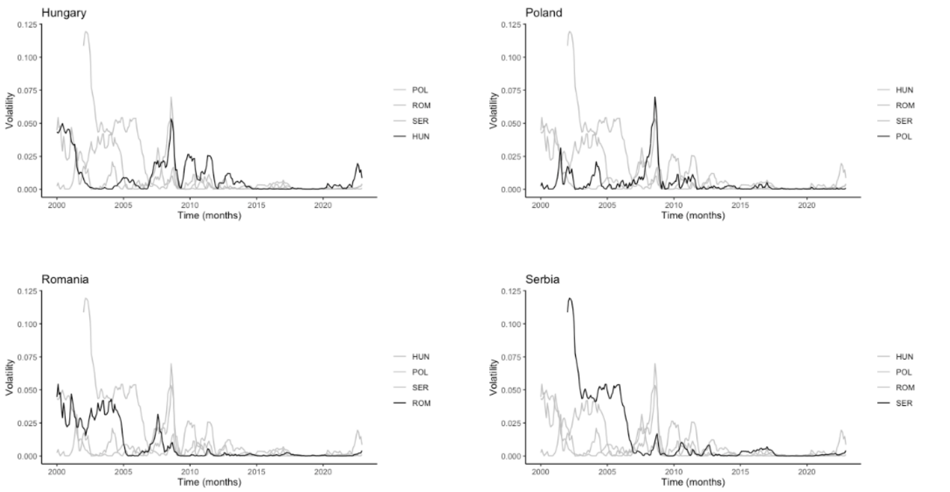
*Notes:***, ** and * indicate that the null hypothesis of no causation is rejected at the 1%, 5% and 10% significance levels, respectively.*
The numbers in parentheses are standard errors. Δ is the first difference operator.
The number of appropriate lag is one according to Akaike information criterion.

Causality tests results also indicate the existence of short-term and long-term causal relations between REER and other variables providing evidences that our ARDL and NARDL results are robust. Regarding Hungary all variables do Granger cause exports, imports and industrial production in the long-run. In the case of Poland there is a long-run causality between industrial production and other variables. As for Romania the results indicate long-run causality between industrial production, imports and exports and other variables. Regarding Serbia all variables do Granger cause industrial production and exports in the long run.

5.2 Estimating the GARCH model

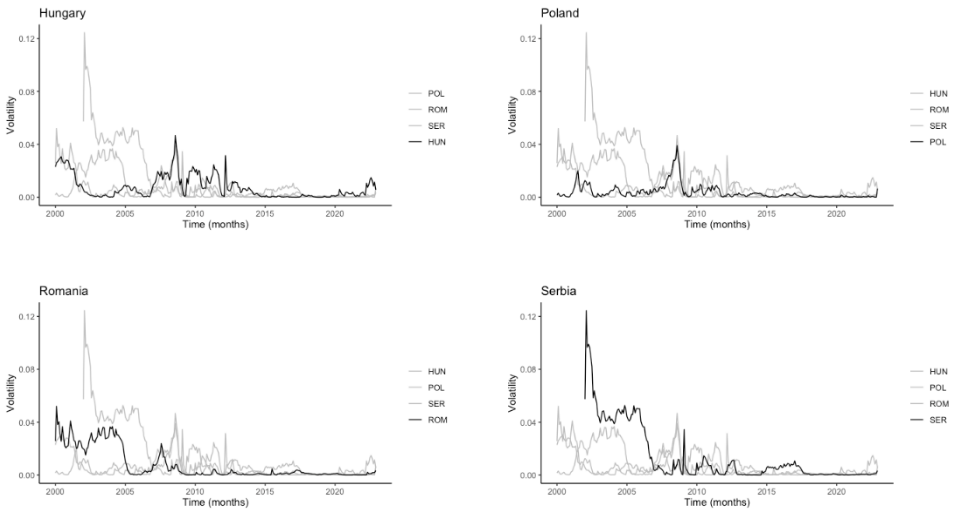
The volatility of the monthly log yields for the REER time series was estimated by means of the GARCH (1,1) and EGARCH models. The estimated volatility is presented in figures 3 and 4.

Figure 3. Estimated volatility by the GARCH(1,1) model



Source: The authors.

Figure 4. Estimated volatility by the EGARCH model



Source: The authors.

Obviously, Poland experienced greater REER volatility than the other countries, as well as more the frequent appearance of extreme values for the REER. Romania experienced smaller volatility of REER. Tables 6 and 7 show the summary statistics of volatility by country for the periods before and after the GFC.

Table 6. Summary statistics of volatility by country GARCH

country_name	type	period	min	q1	median	q3	max
Hungary	GARCH	Before 2009	0	0.00	0.01	0.02	0.05
Hungary	GARCH	After 2009	0	0.00	0.00	0.01	0.03
Poland	GARCH	Before 2009	0	0.00	0.00	0.01	0.07
Poland	GARCH	After 2009	0	0.00	0.00	0.00	0.01
Romania	GARCH	Before 2009	0	0.01	0.02	0.03	0.05
Romania	GARCH	After 2009	0	0.00	0.00	0.00	0.01
Serbia	GARCH	Before 2009	0	0.01	0.04	0.05	0.12
Serbia	GARCH	After 2009	0	0.00	0.00	0.00	0.01

Source: The authors.

Table 7. Summary statistics of volatility by country EGARCH

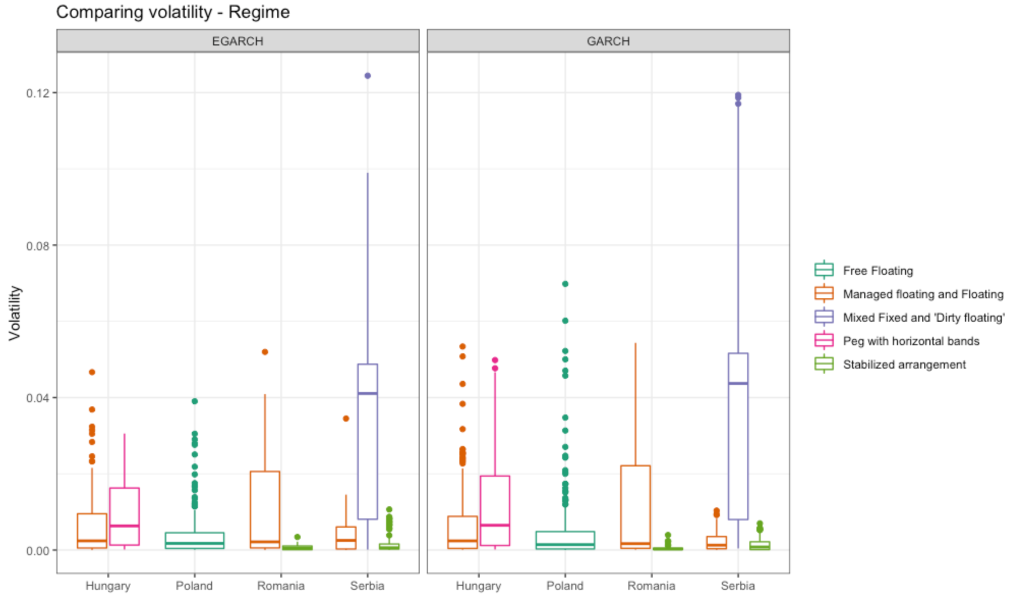
country_name	type	period	min	q1	median	q3	max
Hungary	EGARCH	Before 2009	0	0.00	0.01	0.02	0.05
Hungary	EGARCH	After 2009	0	0.00	0.00	0.01	0.03
Poland	EGARCH	Before 2009	0	0.00	0.00	0.01	0.04
Poland	EGARCH	After 2009	0	0.00	0.00	0.00	0.01
Romania	EGARCH	Before 2009	0	0.00	0.02	0.03	0.05
Romania	EGARCH	After 2009	0	0.00	0.00	0.00	0.00
Serbia	EGARCH	Before 2009	0	0.01	0.04	0.05	0.12
Serbia	EGARCH	After 2009	0	0.00	0.00	0.01	0.03

min - Minimum (Q0 or 0th percentile)
q1 - First quartile (Q1 or 25th percentile)
median - Median (Q2 or 50th percentile)
q3 - Third quartile (Q3 or 75th percentile)
max - Maximum (Q4 or 100th percentile)

Source: The authors.

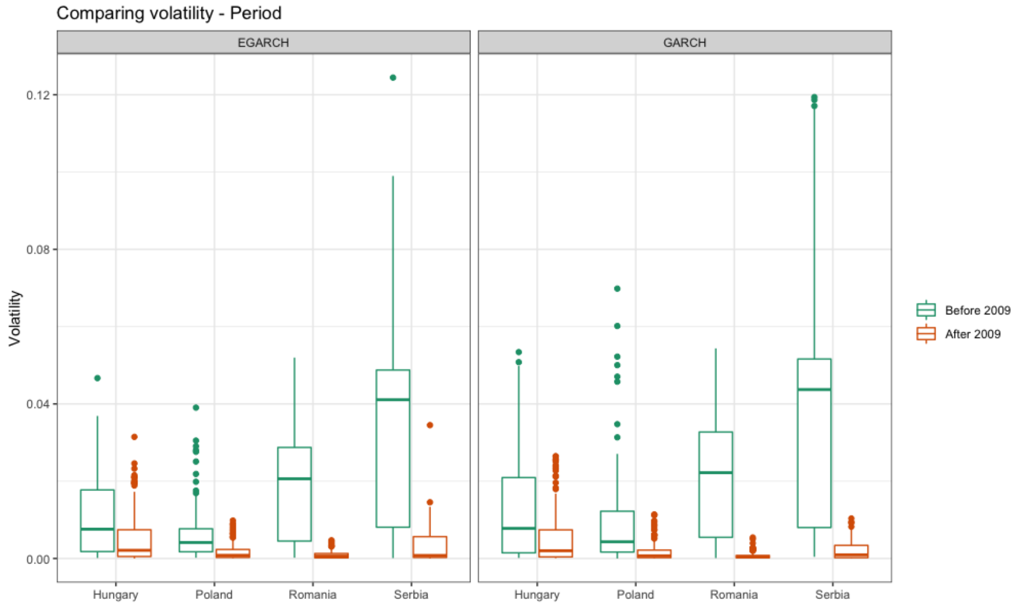
After the GFC, the values for the GARCH were the highest for Poland and Hungary. In contrast, they were significantly lower for Romania and Serbia. Tables 6 and 7 indicate that the obtained results are similar for both GARCH and EGARCH models. Figures 5 and 6 present a boxplot of the monthly values for the estimated volatility of REEF by country and exchange rate regime and by country for the periods before and after 2009, respectively.

Figure 5. Comparing volatility by country and exchange rate regime



Source: The authors.

Figure 6. Comparing volatility by country for the periods before and after 2009



Source: The authors.

Tables 8 and 9 present the average and median values of the quarterly growth rates of exports, imports and industrial production for the periods before and after the onset of the GFC.

Table 8. Comparing the average values of the growth rates before 2009

Country	*Export (mean)*	*Import (mean)*	*Production (mean)*	*Export (median)*	*Import (median)*	*Production (median)*
Hungary	11.94	10.75	5.80	13.23	11.47	6.71
Poland	8.83	8.25	6.54	9.87	10.04	7.23
Romania	9.38	17.62	3.39	9.34	16.64	2.31
Serbia	17.75	25.28	2.07	15.11	18.36	2.78

Source: The authors.

Table 9. Comparing the average values of the growth rates after 2009

Country	*Export (mean)*	*Import (mean)*	*Production (mean)*	*Export (median)*	*Import (median)*	*Production (median)*
Hungary	5.10	5.13	4.03	5.56	5.84	4.62
Poland	6.63	6.05	6.07	6.50	6.61	5.84
Romania	8.33	7.91	5.63	7.00	8.94	4.07
Serbia	9.02	6.15	1.89	8.23	6.99	2.78

Source: The authors.

High REER volatility in Poland with free floating exchange rate regime did not impact negatively the growth of industrial production and exports. Conversely, REER was an important adjustment mechanism to mitigate negative exogenous shocks, allowing Poland to avoid significant fall in exports and industrial production following the GFC. The decrease in exports and industrial production was recorded only in 2009. As for the effects on exports, the same applies to Hungary which experienced slightly lower REER volatility in comparison to Poland with the chosen managed floating and floating regime after the onset of the GFC. However, the fall in industrial production after the emergence of GFS in 2009 was higher than in Poland (see Figure 3 and Appendix A). Contrary to that, low REER volatility in the period after the GFC, with the chosen managed floating regime and stabilized arrangement, was followed by the lowest growth rates for industrial production in the case of Serbia (Table 6). Mainly, this reflected Serbia's high and long-term dependence on import components.

6. Conclusion

After the onset of the GFC, the issue of choice of the optimal exchange rate regime was again one of the most important ones for EME. Such a choice should be based, among other things, on quantifying the influence of the REER on the real sector of the economy. On the basis of the estimation of the REER's influence on industrial production, exports and imports in four EME with targeted inflation which, after the onset of the GFC, implemented one of two variants of the floating exchange rate regime, we reached several conclusions. Based on the Bounds tests, we can conclude that after 2000, there are evidences of long-run relationships among the REER, industrial production, exports and imports in four countries - Hungary, Poland, Romania and Serbia. These results confirm that there is a relationship between REER and industrial production, exports and imports (Auboin & Ruta (2011), Chaudhary, Hashmi & Khan (2016), Alam & Qazi (2012), Sugiharti, Esquivias & Setyorani (2020)). We also point out that results are mixed depending on the exchange rate regime (free floating vs. managed and floating exchange rate). Short-term and long-term Granger causality tests support the view that REER is one of the key factors affecting the industrial production, exports and imports.

The estimation of the GARCH and EGARCH models shows that REER volatility was the highest in Poland and the lowest in Romania and Serbia. High REER volatility in the selected free-floating regime in Poland was an important adjustment mechanism to mitigate negative exogenous shocks, allowing Poland to avoid significant fall in exports and industrial production following the GFC. As for the effects on exports, the same applies to Hungary which experienced slightly lower REER volatility in comparison to Poland with the chosen managed floating and floating regime after the onset of the GFC. Contrary to that, low REER volatility in the period after the GFC, with the chosen managed floating regime and stabilized arrangement, was followed by the lowest growth rates for industrial production in the case of Serbia. Therefore, high REER volatility in countries with targeted inflation could serve as an absorber of negative external shocks during the crisis by stimulating the growth of exports and industrial production. These results could be useful for selecting optimal exchange rate regime under inflation targeting by supporting industry growth and international trade in CEE countries. Further research could be directed towards examining the influence of the REER on disaggregated sectoral data for industrial production, export and import in selected EME.

References

Alam, S. & Qazi M., 2012. Exchange rate volatility and aggregate exports demand through ARDL framework: An experience from Pakistan economy. *Review of Applied Economics,* 8(1), pp.79-93. https://doi.org/10.22004/ag.econ.143465.

Auboin, M. & Ruta, M., 2011. The relationship between exchange rates and International Trade: A review of economic literature. *WTO Staff Working Paper, No. ERSD-2011-17, 27*.

Arize, A.C., 2017. A convenient method for the estimation of ARDL parameters and test statistics: USA trade balance and real effective exchange rate relation. *International Review of Economics & Finance*, 50, pp.75-84. https://doi.org/10.1016/j.iref.2017.03.024.

Batten, J.A., Ciner, C, Lucey, B.M., 2010. The macroeconomic determinants of volatility in precious metals markets, *Resources Policy*, 35(2), pp.65-71. https://doi.org/10.1016/j.resourpol.2009.12.002.

Berthou, A., 2008. An investigation on the effects of real exchange rate movements on OECD bilateral exports. *European central Bank Working Paper Series*, *No 920*. http://dx.doi.org/10.2139/ssrn.1157776.

Bošnjak, M., Kordić, G. & Novak, I., 2021. Real Effective Exchange Rate and Industrial Productivity in Croatia: Wavelet Coherence Analysis. *South East European Journal of Economics and Business*, 16(1), pp.30-37. https://doi.org/10.2478/jeb-2021-0003.

Brownlees, C., Gallo, M., 2010. Comparison of volatility measures: a risk management perspective. *Journal of Financial Econometrics,* 8(1), pp.29–56. https://doi.org/10.1093/jjfinec/nbp009.

Chaudhary, G.M., Hashmi, S.H. & Khan, M.A., 2016. Exchange Rate and Foreign Trade: A Comparative Study of Major South Asian and South-East Asian Countries. *Procedia - Social and Behavioral Sciences, 230*, pp.85–93. https://doi.org/10.1016/j.sbspro.2016.09.011.

Cizmović, M., Shachmurove, Y. & Vulanovic, M., 2021. Real Effective Exchange Rates and deindustrialization: Evidence from 25 Post-Communist Eastern European Countries.

Post-Communist Economies, 33(7), pp.863–899. https://doi.org/10.1080/14631377.2020.1867429.

Dyhrberg, A.H., 2016. Bitcoin, Gold and the Dollar–A GARCH volatility analysis. *Finance Research Letters,* 16, pp.85–92. https://doi.org/10.1016/j.frl.2015.10.008.

Ebeke, C. & Azangue, A.F., 2015. Inflation Targeting and Exchange Rate Regimes in Emerging Markets. *International Monetary Fund Working Paper, WP/15/228.*

Frankel, J., 2011. Choosing an Exchange Rate. *M-RCBG Faculty Working Paper No. 2011-16, Harvard Kennedy School*, pp.1-35. Available at: <https://www.hks.harvard.edu/sites/default/files/centers/mrcbg/files/MRCBG_FWP_2011_16-2011_Frankel_Exchange_Rate.pdf> [Accessed June 2022].

Genc, E.G. & Artar, O.K., 2014. The Effects of Exchange Rates on Exports and Imports of Emarging Countries. *European Scientific Journal, 10(13)*, pp.85-102. https://doi.org/10.19044/esj.2014.v10n13p%25p.

Ghosh, A.R., Ostry, J. D. & Qureshi. M. S. 2014. Exchange Rate Management and Crisis Susceptibility: A Reassessment. *IMF Working Paper WP/14/11.*

Habermeier, K., Kokenyne, A., Veyrune, R. & Anderson, H., 2009. Revised System for the Classification of Exchange Rate Arrangements. *IMF Working paper WP/09/211*.

Habib, M., Mileva, M. E. & Stracca, L., 2016. The real exchange rate and economic growth: Revisiting the case using external instruments. *European Central Bank Working Paper series, 1921*. http://dx.doi.org/10.2139/ssrn.2797378.

Hassan, R. Chakraborty, S., Sultana, N. & Rahman, M., 2016. The impact of the real effective exchange rate on real export earnings in Bangladesh. *Working Paper Series: WP No 1605, Monetary Policy and Research Department, Bagladesh Bank.* Available at: <https://www.bb.org.bd/pub/research/workingpaper/wp1605.pdf> [Accessed June 2022].

IMF., 2006. The IMF's advice on Exchange rate Policy. *Issues Paper for an Evaluation by the Independent Evolution Office (IEO), June 23.* Available at: <http://www.ieo-imf.org/ieo/files/issuespapers/041906.pdf> [Accessed June 2022].

IMF., 2014. Annual Report on Exchange Arrangements and Exchange Restrictions. Available at: <https://www.imf.org/en/Publications/Annual-Report-on-Exchange-Arrangements-and-Exchange-Restrictions/Issues/2016/12/31/Annual-Report-on-Exchange-Arrangements-and-Exchange-Restrictions-2014-41643> [Accessed June 2022].

IMF., 2016. Annual Report on Exchange Arrangements and Exchange Restrictions. Available at: <https://www.imf.org/en/Publications/Annual-Report-on-Exchange-Arrangements-and-Exchange-Restrictions/Issues/2017/01/25/Annual-Report-on-Exchange-Arrangements-and-Exchange-Restrictions-2016-43741> [Accessed April 2023].

IMF., 2017. Annual Report on Exchange Arrangements and Exchange Restrictions. Available at: <https://www.imf.org/en/Publications/Annual-Report-on-Exchange-Arrangements-and-Exchange-Restrictions/Issues/2018/08/10/Annual-Report-on-Exchange-Arrangements-and-Exchange-Restrictions-2017-44930. [Accessed June 2022].

Johansen, S., 1988. Statistical analysis of cointegration vectors. *Journal of Economic Dynamics and Control, 12(2–3)*, pp.231–254. https://doi.org/10.1016/0165-1889(88)90041-3.

Kemal, M.A. & Qadir, U., 2005. Real exchange rate, exports, and import movements: A trivariate analysis. *The Pakistan Development Review, 44(2), pp.*177–195.

Lanau, S. 2017. The Sectoral Effects of Real Depreciations in Latin America. *IMF Working Paper, WP/17/249*.

Ozturk, I. & Kalyoncu, H., 2009. Exchange Rate Volatility and Trade: An Empirical Investigation from Cross-Country Comparison. *African Development review, 21(3),* pp.499-513. https://doi.org/10.1111/j.1467-8268.2009.00220.x.

Ozturk, I., 2006. Exchange Rate Volatility and Trade: A Literature Survey. *International Journal of Applied Econometrics and Quantitative Studies*, *3-1*, 85-102. Available at: < http://www.usc.es/economet/reviews/ijaeqs315.pdf

Özer, M., Kamenković, S. & Grubišić, Z., 2020. Frequency domain causality analysis of intra- and inter-regional return and volatility spillovers of South-East European (SEE) stock markets. *Economic research - Ekonomska istraživanja*, 33(1), pp.1-25. https://doi.org/10.1080/1331677X.2019.1699138

Pesaran, M.H. & Shin, Y., 2013. An Autoregressive Distributed-Lag Modelling Approach to Cointegration Analysis. *In: Steinar Strøm, ed., Econometrics and Economic Theory in the 20th Century.* Cambridge University Press*, pp.*371-413. https://doi.org/10.1017/CCOL521633230.011

Pesaran, M.H., Shin, Y. & Smith, R., 2001. Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics,* 16(3), pp.289-326.

Rajan, S.R., 2012. Management of exchange rate regimes in emerging Asia. *Review of Development Finance, 2,* pp.53–68.

Rapetti, M., Skott, P. & Razmi, A., 2011. The real exchange rate and economic growth: Are developing countries different?. *University of Massachusetts, Economic Department Working Paper Series*, 115, March 5. https://doi.org/10.7275/3317868.

Rodrik, D., 2008. The real exchange rate and economic growth. *Brookings Papers on Economic Activity, 39*(2), pp.365-439.

Shin, Y., Yu, B. Greenwood-Nimmo, M., Sickles, R.C. & Horrace, W.C., 2014. *Modelling Asymmetric Cointegration and Dynamic Multipliers in a Nonlinear ARDL Framework*. Festschrift in Honor of Peter Schmidt: Econometric Methods and Applications, pp.281–314, Springer New York. https://doi.org/10.1007/978-1-4899-8008-3_9.

Sugiharti, L., Esquivias, M.A. & Setyorani, B., 2020. The impact of exchange rate volatility on Indonesia's top exports to the five main export markets. *Heliyon*, 6(1), e03141. https://doi.org/10.1016/j.heliyon.2019.e03141.

Tsay, S.R., 2010. *Analysis of Financial Time Series*. 3rd Edition, John Wiley & Sons, Hoboken. https://doi.org/10.1002/9780470644560.

Twarowska, K., 2015. The Impact of Exchange Rate on Poland's Trade Flows. *International Journal of Management, Knowledge and Learning*, 4(1), pp.41–57.

Zivot, E. & Andrews, D.W.K., 1992. Further evidence on the great crash, the oil price shock, and the unit root hypothesis. *Journal of Business & Economic Statistics*. 10(3), pp.251-270. https://doi.org/10.2307/1391541.

Zhou, Z., Zhangyan Fu, Yong Jiang, Ximei Zeng, Ling Lin, 2020. Can economic policy uncertainty predict exchange rate volatility? New evidence from the GARCH-MIDAS model*. Finance Research Letters*, 34, 101258. .https://doi.org/10.1016/j.frl.2019.08.006.