Real Exchange Rates Behavior in Selected EU Member States: Assessment of the Financial Crisis Effect

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Abstract
The real exchange rate is one of the crucial macroeconomic variables for all open economies. Therefore, analysis of its evolution as well as volatility and behavior of its components (nominal exchange rate and relative prices) is of critical importance for both the economic theory and economic policy. In this paper, we focus on the interaction among the component variables of the real exchange rate. The main objective of this paper is evaluate how the relative prices affect the exchange rate. We calculate volatility measure and apply the Granger causality test, variance decomposition and impulse-response function in the Vector Auto Regression model for six selected non-euro EU member states (Czechia, Hungary, Poland, Denmark, Sweden and the United Kingdom). The calculations are conducted for two periods distinguished as the pre-crisis period and the post-crisis period. The results differ substantially between the periods and provide evidence that the relative prices play more important role in explaining the exchange rate behavior in the post-crisis period than before its origin.

Keywords: real exchange rate, volatility, Granger causality, variance decomposition, impulse-response function
JEL codes: E32, E44, F31

1. Introduction

The real exchange rate is one of the most important indicators in macroeconomics and economic policy as its changes and fluctuations have implications for both external competitiveness as well as resource allocation within the economy. The real exchange rate also plays a crucial role in numerous models of the open economy. The questions on real exchange rate development, determinants, volatility and effects have been frequently posted in economic research. The importance of real exchange rate and its monitoring even increased in recent years as a growing share of economic activities are directly or indirectly affected by economic development in other economies. Moreover, all the issues associated with the real exchange rate behavior have taken on heightened importance in the current period of economic slowdown and recession. Since the real exchange rate is one of the most comprehensive indicators of the country's competitiveness on international markets, the cross-country comparisons point to future prospects of the country's economy and provides a good guidance for the officials, businessmen and international organizations.

This paper focuses on volatility of the real exchange rate. The relevant literature in this area can be divided into four categories. According to Ouyang and Rajan (2013), the first stream of literature links the volatility to the exchange rate arrangement and attributes the increase in volatility to the shift from fixed to flexible exchange rate regime. The second set of studies generally use Vector Auto Regression (VAR) methods and variance decomposition procedures to identify relative contribution of real and nominal shocks to the real exchange rate fluctuations. The third category of literature deals with the fundamental determinants of the long-run equilibrium real exchange rate such as productivity, investment position, foreign investment or fiscal indicators. The fourth line of literature employs various techniques to decompose real exchange rate volatility into its two subcomponents – external prices (deviations from the Purchasing Power Parity) and internal prices (relative price of tradeable and non-tradeable goods).

This study examines behavior of the real exchange rate in selected EU member states outside the euro area. In particular, we investigate the interaction among the component variables of the real exchange rate, i.e. exchange rate and relative prices. The main aim of the paper is to find out whether the causality that movement of exchange rate is influenced by changes in relative prices hold and to evaluate the degree of impact of the relative prices on the exchange rate. Moreover, the paper brings a new perspective into the analysis as it compares the real exchange rate behavior and interaction between the components in the pre-crisis and post-crisis periods. The group of selected countries includes six non-euro EU member states out of which three are new member states from the Central Europe (Czechia, Hungary, Poland) and three countries are traditional developed EU members (Denmark, Sweden, United Kingdom). Hereafter, the countries are denoted as CZ, HU, PL, DK, SE, and UK, respectively.

2. Data and Research Methodology

The real exchange rate can be expressed as the nominal exchange rate adjusted for relative price level differences between domestic and foreign economy. In order to obtain the real exchange rate in logarithmic form one can employ the standard formula (1):

$$q_t \equiv s_t + p_t - p_t^* \tag{1}$$

where q_t is the real exchange rate, s_t is the nominal exchange rate, p_t is the domestic price level and p_t^* is the foreign price level.

The data are all collected from the Economy and Finance database available on the Eurostat website. All data are on monthly basis and cover two periods. In order to obtain consistent results we exclude the crisis period (2008:01 – 2009:06) from our analysis and compare the real exchange rates behavior in the pre-crisis and post-crisis period. The pre-crisis period covers 2002:01 – 2007:12 and the post-crisis period spans from 2009:07 to 2015:06. Hence, both periods include 72 monthly observations. The nominal exchange rate represents monthly average of daily spot exchange rates of national currencies against the euro and it is quoted as the price of euro in national currency units. The price levels are HICP indices defined as 2005=100. The price level in the euro area is taken as the foreign price level for computation of the real exchange rate.

The first empirical tool to investigate real exchange rate behavior is computation of volatility. We apply the measure of volatility used by Hausmann et al. (2006), which is the standard deviation of the growth rate of the real exchange rate. Formally, our volatility measure is given by

$$vol_i = \frac{SD(\ln(q_{i,t}) - \ln(q_{i,t-n}))}{\sqrt{n}} \tag{2}$$

where n is the number of quarters. We experiment with the one-month and three-month volatility indicators and compare the results between the periods and across the countries.

In the next step of empirical analysis we examine the relationship between the two components of the real exchange rate, i.e. the nominal exchange rate and the relative prices. This analysis is conducted by means of a VAR model. Before setting up the VAR model we verify the long-run stability of the two real exchange rate components using two alternative unit root tests. In particular, we apply the augmented Dickey-Fuller (ADF) and the Phillips-Peron (PP) tests in order to examine stationarity of all series during the pre-crisis and post-crisis periods. Since both test have been extensively used in literature their formal derivation and formulation are not presented in the paper. However, it is worth to note that the ADF test accounts for temporally dependent and heterogeneously distributed errors by including lagged innovation sequences in the fitted regression. By contrast, the PP test accounts for non-independent and identically distributed processes using a non-parametric procedure. Since the ADF test relies on a parametric procedure to correct for autocorrelation and heterogeneity, the PP test is often favored over the ADF test in term of power (Taguchi, 2010).

By application of the VAR model we can consequently use number of related techniques to shed some light on the main channels of interaction among the variables in the system, i.e. the nominal

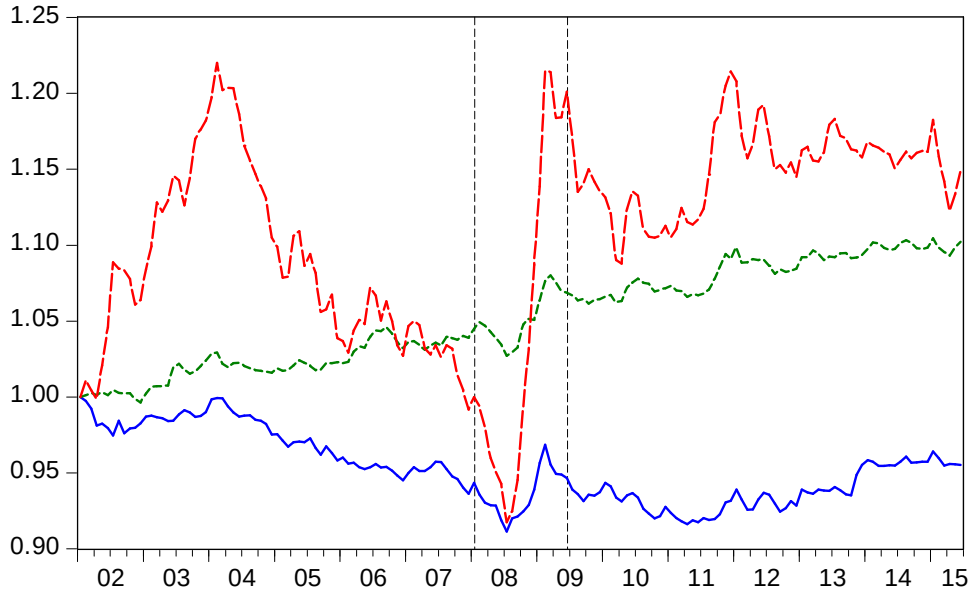
exchange rate and the relative prices. Namely we use the Granger causality test, variance decomposition and impulse-response analysis.

The Granger causality refers to a specific notion of causality in time-series analysis. A time series *X* is said to Granger-cause *Y* if it can be shown, usually through a series of t-tests and F-tests on lagged values of *X* (and with lagged values of *Y* also included), that those *X* values provide statistically significant information about future values of *Y*. The variance decomposition represents the proportion of the total variance of each variable that is attributable to each of the orthogonalized innovations. It measures the overall relative importance of an individual variable in generating variations due to its own shock as well as shocks due to other variables in the system. Because the Granger causality may not show the full picture about the interactions between the variables of the system we also apply the impulse response functions. These functions trace the dynamic responses to the effect of a shock in one endogeneous variable on all endogeneous variables in the system. In other words, the impulse response functions map out the dynamic response path of a variable due to a one-period standard deviation shock to another variable.

3. Real Exchange Rates Development and Volatility

Before we start examining volatility of the real exchange rates it is crucial to demonstrate and discuss evolution of real exchange rates in all analyzed countries. We present the development in the new EU member states in Figure 1 and the development in traditional member states in Figure 2. For graphical convenience, we choose to study all currencies under the base 2002 = 100. An increase in the index represents a weakening of the local currency and strengthening of the euro. The two dashed vertical lines mark out the pre-crisis period (2002:01 – 2007:12), the crisis period (2008:01 – 2009:06) and the post-crisis period (2009:07 – 2015:06).

Figure 1: Real Exchange Rates Evolution in New EU Member States (2002:01 – 2015:06)



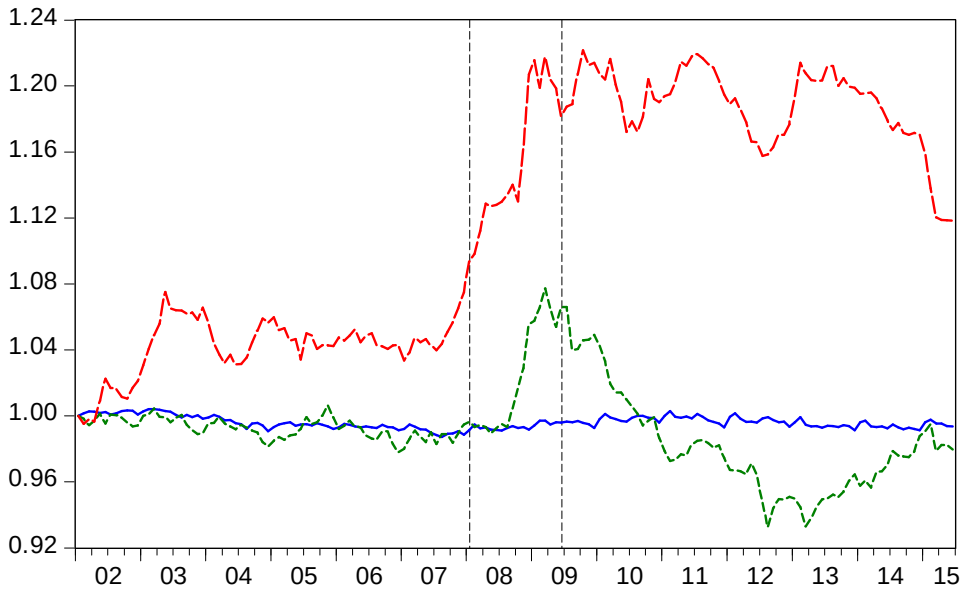
Source: author's calculations based on data from the Eurostat Economy and Finance database

One can distinguish very different development of the real exchange rates in the new member states during the pre-crisis period. While the Czech koruna experienced a gradual real appreciation of 6.5%, the Hungarian forint depreciated in real terms of about 4%. The most turbulent evolution can be observed in the case of Polish zloty. Although the real exchange rate at the end of the pre-crisis period was almost identical with the value at the beginning the zloty initially depreciated of about 22% over the first two years and then appreciated back during the remaining four years. The post-crisis

development of the real exchange rates seems to be more homogeneous in the group of new member states as the Polish zloty was oscillating around a certain and relatively stable level. The change of the real exchange rate during the post-crisis period is not remarkably high in none of the countries. Whereas the Polish zloty appreciated of 4%, the Czech koruna and Hungarian forint depreciated of 1% and 3%, respectively.

When comparing the real exchange rate evolution in traditional non-euro EU member states the exchange rate arrangement in Denmark should be taken into account. Denmark maintains a fixed-exchange-rate policy vis-à-vis the euro area and participates in the European Exchange Rate Mechanism, ERM 2, at a central rate of 746.038 kroner per 100 euro with a fluctuation band of +/- 2.25%. Therefore, the relative stability of the Danish kroner nominal exchange rate is transferred into stability of the real exchange rate and one can see almost no exchange rate fluctuations over the whole period analyzed. During the pre-crisis period the Swedish korona and British pound also experienced a stable development. The only exception was the 8% real depreciation of the pound in 2003. The overall changes of the real exchange rates in the pre-crisis period are as follows: Danish kroner appreciated of 1%, Swedish korona appreciated of 0.5%, and British pound depreciated in real terms of 7.5%. By contrast, the post-crisis period is more turbulent for both the Swedish korona and the British pound. As typically documented in currency and financial crisis, the real exchange rate overshoots at the shock and then appreciates after some time (Coudert et al., 2011). However, this is the only one common feature attributable to both currencies. The Swedish korona started the post-crisis period with real appreciation that was replaced by depreciation after four years. As a result, the korona appreciated of 8% during the post-crisis period. The British pound was oscillating around the starting level during the first four years and then embarked on appreciation path, which resulted to overall appreciation of 5.5%.

Figure 2: Real Exchange Rates Evolution in Traditional EU Member States (2002:01 – 2015:06)



Source: author's calculations based on data from the Eurostat Economy and Finance database

As Mabin (2010) points out the short-term volatility reflects month-to-month changes in real exchange rates, up to a maximum of one year. We can observe this as the exchange rate moves around the cyclical exchange rate. These fluctuations in the real effective exchange rate usually stem from changes in the nominal exchange rate. We compute and examine the volatility of the real exchange rate by a measure formulated in (1). Following the approach of Mollick (2009), the volatility indicator is calculated for each exchange rate over three different periods, i.e. the whole period covered by the dataset (2002:01 – 2015:06), the pre-crisis period and the post-crisis period. Subsequently, we compute

the growth rate in volatility between the two sub-periods. Moreover, the volatility was calculated from one-month and three-month changes of the real exchange rates. The results are summarized in Table 1.

Table 1: Volatility of Real Exchange Rates

	2002 – 2015	2002 – 2007	2009 – 2015	Change 09-15 – 02-07
	1-month volatility			
CZ	0.016349	0.012981	0.014905	14.83 %
HU	0.021185	0.017269	0.019753	14.38 %
PL	0.022525	0.019457	0.018351	-5.68 %
DK	0.003738	0.002862	0.004439	55.10 %
SE	0.014065	0.008927	0.015179	70.05 %
UK	0.017002	0.012227	0.015840	29.55 %
	3-month volatility			
CZ	0.017902	0.013255	0.015791	19.13 %
HU	0.023977	0.017947	0.021042	17.24 %
PL	0.028370	0.022184	0.019850	-10.52 %
DK	0.003016	0.002458	0.003433	39.68 %
SE	0.015520	0.007747	0.016006	106.61 %
UK	0.019799	0.013334	0.018622	39.65 %

Source: author's calculations

Two crucial findings can be revealed in the results. First, the volatility of the real exchange rate is higher in the new member states than traditional members. A substantial difference in volatility between the two groups of countries can be found particularly in the pre-crisis period. The volatility converged significantly during the post-crisis period and volatility of the Czech koruna real exchange rates is even lower than volatility of the Swedish korona and British pound. Second, the growth rate of volatility between the pre-crisis and post-crisis periods is considerably higher in the group of traditional EU member states the in the newcomers. Similar finding for real effective exchange rates are presented by Stavárek and Miglietti (2015). Focusing on the one-month volatility, one can observe that the range of growth rates for the new member states is from -5.68% in Poland to +14.83% in Czechia. By contrast, the growth rates in the group of traditional EU members vary from +29.55% in the UK to +70.05% in Sweden. A very similar picture is revealed if one concentrates on the three-month volatility. While the volatility in the new members changed from -10.52% in Poland to +19.13% in Czechia the growth rates in the group of traditional members range from +39.68% in Denmark to +106.61% in Sweden.

4. Interaction between the Real Exchange Rate Components

In this section we report and discuss results of the Granger causality tests, variance decompositions and impulse-response functions in order to examine the interaction between the nominal exchange rate and relative prices. The major concern in these analyses is to prove the causality from the relative prices to the exchange rate and to determine the degree of impact of the relative prices to the exchange rate.

Before conducting all the mentioned empirical procedures, we test individually for unit roots on all components of the real exchange rate using the ADF and PP tests. These results are omitted for space constraints but are available upon request. The ADF and PP tests equally do not reject the unit root null hypothesis in levels and does reject it in first-differences. This finding is revealed for the pre-crisis as well as the post-crisis period. Therefore, one can conclude that the nominal exchange rates and relative prices follow I(1) processes at standard significance level in all countries analyzed. Based on this conclusion we can proceed with construction of VAR models and application of associated analyses.

Table 2: Granger Causality Test

		2002 – 2007		2009 – 2015	
		F statistics	Probability	F statistics	Probability
CZ	ER -/- Pdif	0.3624	0.6974	10.6851	0.0001*
	Pdif -/- ER	0.1040	0.9013	5.0074	0.0097*
HU	ER -/- Pdif	0.5247	0.5944	0.2203	0.8028
	Pdif -/- ER	4.8247	0.0112**	1.3989	0.2540
PL	ER -/- Pdif	1.1558	0.3213	2.5295	0.0873***
	Pdif -/- ER	2.0955	0.1314	1.5027	0.2299
DK	ER -/- Pdif	1.8815	0.1607	3.1949	0.0473**
	Pdif -/- ER	0.3688	0.6930	1.0703	0.3487
SE	ER -/- Pdif	0.4786	0.6218	1.0022	0.3725
	Pdif -/- ER	0.4763	0.6233	1.7876	0.1752
UK	ER -/- Pdif	0.5769	0.5645	0.1299	0.8783
	Pdif -/- ER	1.2054	0.3063	3.9392	0.0241**

Note: ER is the nominal exchange rate, Pdif is the price differential (relative prices), *,**,*** denote significance on 1%, 5% and 10% level, respectively

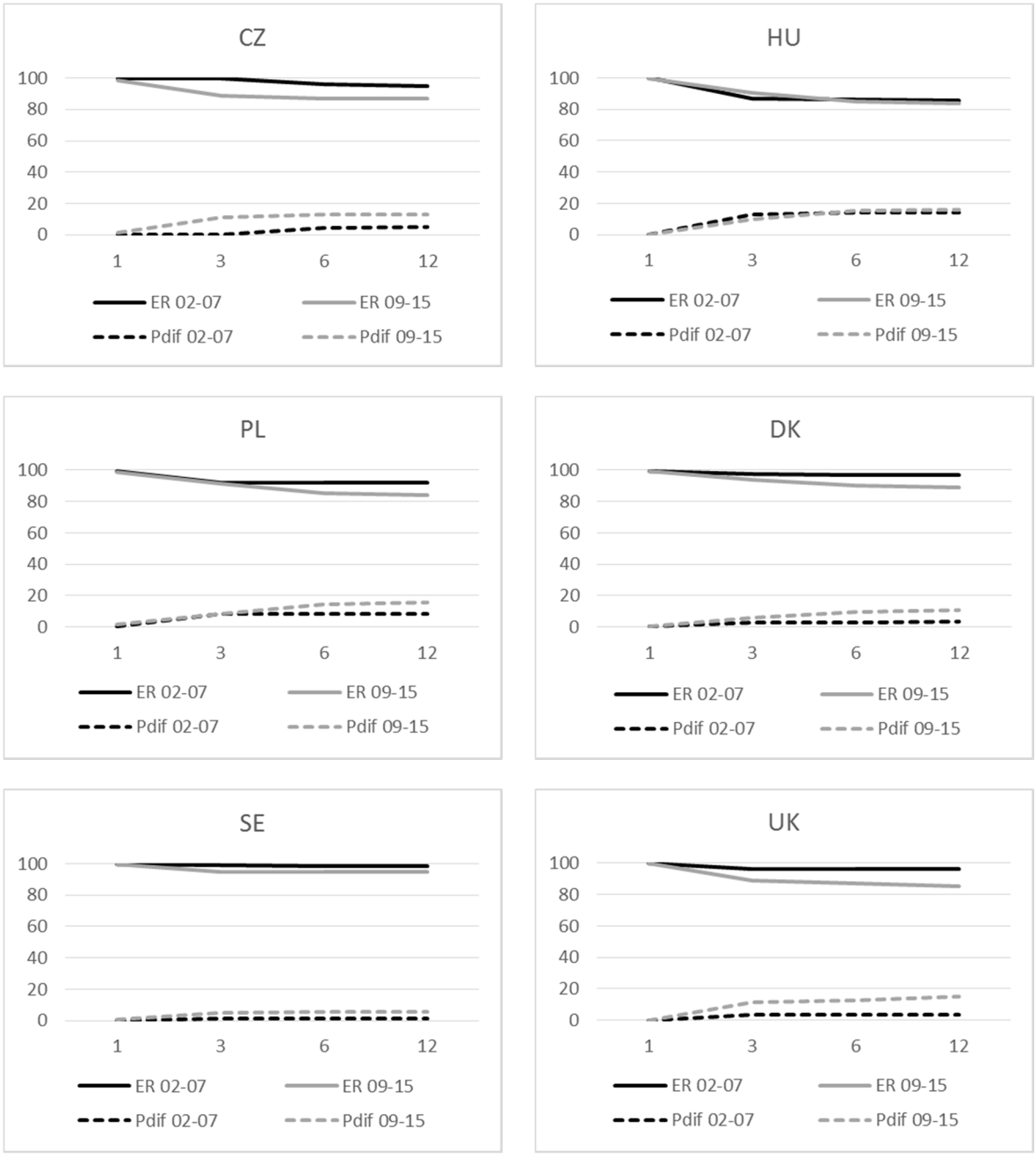
Source: author's calculations

The results of the Granger causality test are given in Table 2. One can find only one example of the Granger causality during the pre-crisis period. The causality from the relative prices to the exchange rate is revealed in Hungary. More evidence on Granger causality between the components of the real exchange rate was discovered in the post-crisis period. There are two cases of causality in which the relative prices Granger-cause the exchange rate (Czechia and United Kingdom). There are three more examples of the reverse causality, i.e. the exchange rate Granger-causes the relative prices (Czechia, Poland, Denmark). One can conclude that the two examined periods yield completely different results as regards the strength and direction of the causality between the variables. However, no general conclusion can be drawn as the results differs across the countries.

The outcomes of the variance decomposition analysis are graphically depicted in Figure 3. In accordance with the main objective of the paper we only report the variance decomposition of the exchange rate in order to realize how much of the exchange rate variations can be explained by the price differential. The share of variance explained by the relative prices usually rises with the increasing time lag. In the pre-crisis period the relative prices explain after 12 months 4.9% of the exchange rate variance in Czechia, 14% in Hungary, 8.1% in Poland, 3.2% in Denmark, 1.5% in Sweden, and 3.7% in the UK. It is evident that the highest contribution of the relative prices was revealed in Hungary, which is the only case of the Granger causality leading from relative prices to exchange rate identified in the pre-crisis period.

As can be seen in the graphs the share of the price differential in the exchange rate variance decomposition increased in all countries during the post-crisis period. Specifically, it was 13% of the variance explained after 12 months in Czechia, 16.3% in Hungary, 15.8% in Poland, 10.8% in Denmark, 5.4% in Sweden and 14.9% in the UK. A noteworthy joint result of the Granger causality tests and variance decomposition analysis appears to be that in all sample countries the relative prices play a more significant role in explaining the exchange rates after the financial crisis than before its outbreak.

Figure 3: Variance Decomposition in the VAR Model

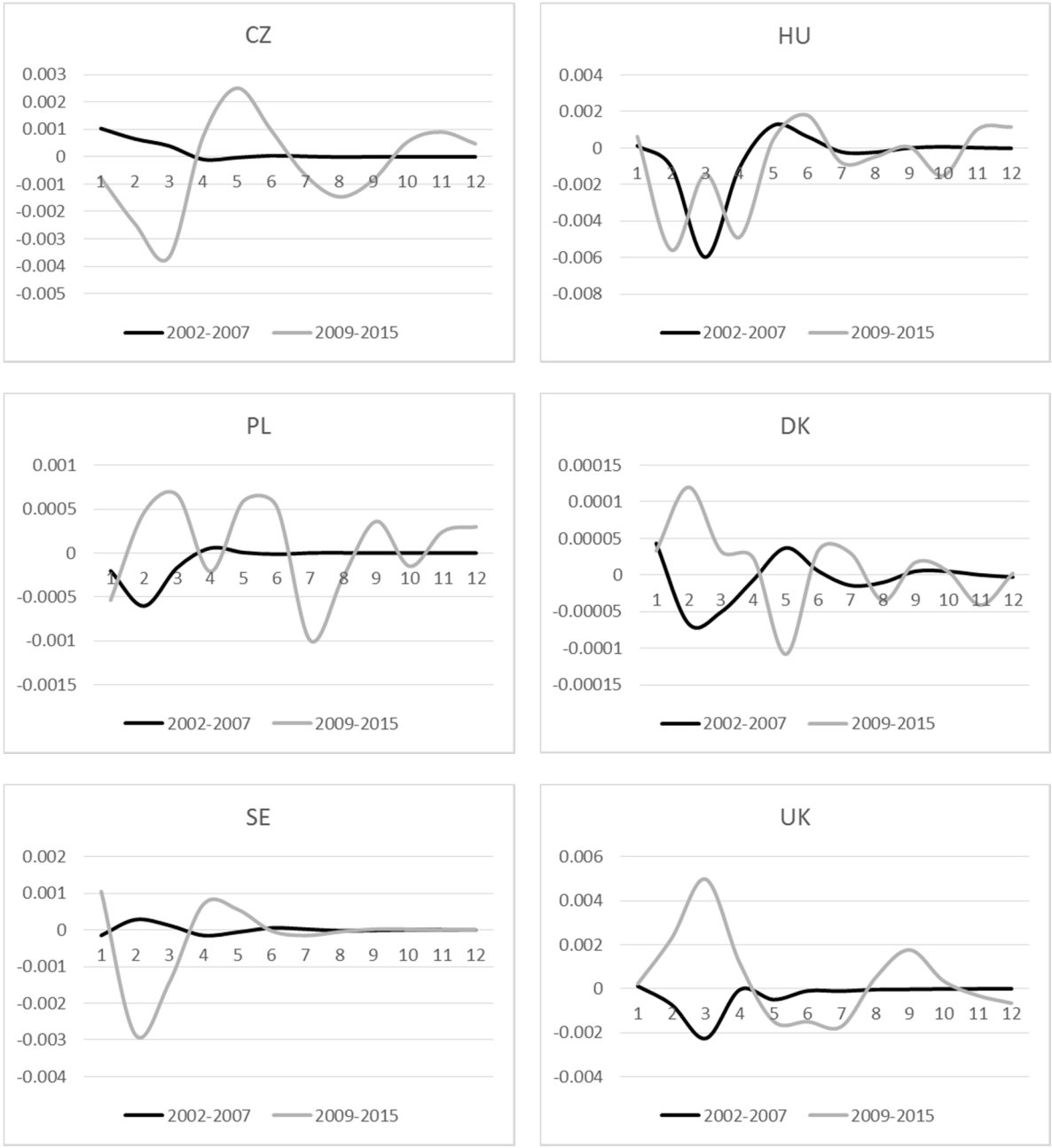


Note: ER is the nominal exchange rate, Pdif is the price differential (relative prices)
Source: author's calculations

Figure 4 shows the dynamic response pattern of the exchange rate to innovation in the price differential by using the impulse-response functions within the constructed VAR model. It is apparent from the functions that the response of the exchange rate to a shock in the relative prices changed considerably in the post-crisis period. In all analyzed countries one can observe that the post-crisis response is more intense, more dynamic and less permanent than the pre-crisis reaction. Additionally, the initial response (1-3 months) was found to be completely opposite when comparing the two periods. For instance, in Czechia and Sweden the shock to relative prices led to depreciation of the national currency in two consecutive months in the pre-crisis period but contributed to its appreciation in the post-crisis period. By contrast, the pre-crisis appreciation in Poland, Denmark and UK was converted into depreciation in the post-crisis period. There is one more remarkable finding that almost all

currencies share in common. While the exchange rate response in the pre-crisis period gradually dies out and is very close to zero after 12 months such a fading in the post-crisis period is apparent only in Sweden. The response of exchange rate of remaining currencies show not negligible values even 12 months after the shock to relative prices.

Figure 4: Impulse-Response Function of Exchange Rate to Shock in Relative Prices



Source: author's calculations

5. Conclusion

The aim of the paper was to find out whether the causality that movement of exchange rate is influenced by changes in relative prices hold and to evaluate the degree of impact of the relative prices on the exchange rate. The analysis was conducted on a diverse sample of six non-euro EU member states. Since our expectation was that the global financial crisis affected behavior of the real exchange

rates as well as interaction among the component variables we run all the tests and estimations for the pre-crisis and post-crisis period. This crisis period (2008:01 – 2009:06) was excluded from our analysis.

The results obtained confirm our expectations as they show substantial differences in findings from the pre-crisis and post-crisis periods. During the pre-crisis period the real exchange rates in the new EU member states exhibit considerably higher volatility than the exchange rates in the traditional members. Although the financial crisis brought a growth of volatility to five of the six countries examined one can identify an unequal effect of the crisis. The post-crisis volatility of the real exchange rates in the traditional member states increased remarkably and reached the level usual in the new members. For instance, the one-month and three-month volatility measures in Sweden increased of 70% and 106% between the periods. By contrast, the same indicators in Poland decreased of 5% and 10%. As a result, the real exchange rate volatility in Czechia was lower than the volatility in Sweden and the United Kingdom during the post-crisis period. It is evident that the crisis changed economic environment more considerably in the traditional member states and the real exchange rate responded by a growing volatility.

We applied the Granger causality test, variance decomposition and impulse-response functions to examine the interaction between the nominal exchange rate and relative prices. Similarly with findings on the volatility one can conclude that the role of relative prices in explaining the exchange rate evolution and behavior is remarkably different in each of the periods analyzed. After the crisis, we revealed significantly more cases of Granger causality between the components of the real exchange rate including the examples where the past values of relative prices help in prediction of future values of the exchange rate. Likewise, the contribution of relative prices in explaining variance of the exchange rate increased remarkably in all sample countries in the post-crisis period. The more pronounced role of relative prices is confirmed also by a shape of the impulse-response functions. After the crisis, the response of the exchange rate to a shock in the relative prices was greater in intensity, dynamics and persistence. The paper, hence, provides empirical evidence that particularly in the post-crisis period we cannot reject the assumption that movement of exchange rate is influenced by changes in relative prices.

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References

COUDERT, V., COUHARDE, C., MIGNON, V. (2011). Exchange rate volatility across financial crises. *Journal of Banking & Finance*, vol. 35, no. 11, pp. 3010–3018.

HAUSMANN, R., PANIZZA, U., RIGOBON, R. (2006). The long-run volatility puzzle of the real exchange rate. *Journal of International Money and Finance*, vol. 25, pp. 93–124.

MABIN, G. (2010). *New Zealand's Exchange Rate Cycles: Evidence and Drivers*. New Zealand Treasury Working Paper 10/10. Wellington: New Zealand Treasury.

MOLLICK, A. V. (2009). Crisis and volatility in Asian versus Latin American real exchange rates. *Économie internatioanale*, vol. 117, pp. 5–29.

OUYANG, A. Y., RAJAN, R. S. (2013). Real exchange rate fluctuations and the relative importance of nontradables. *Journal of International Money and Finance*, vol. 32, pp. 844–855.

STAVÁREK, D., MIGLIETTI, C. (2015). Effective Exchange Rates in Central and Eastern European Countries: Cyclicality and Relationship with Macroeconomic Fundamentals. *Review of Economic Perspectives - Národohospodářský obzor*, vol. 15, no. 2, pp. 157–177.

TAGUCHI, H. (2010). The pre- and post-crisis real exchange rate behavior in selected East Asian countries. *Studies in Regional Science*, vol. 40, no. 1, pp. 27–40.