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REAL EXCHANGE RATES IN SELECTED EU MEMBER STATES. COMPARISON OF PRE-CRISIS AND POST-CRISIS BEHAVIOR

REALNE KURSY WALUTOWE WYBRANYCH PAŃSTW CZŁONKOWSKICH UNII EUROPEJSKIEJ. PORÓWNANIE ZACHOWAŃ SPRZED KRYZYSU I PO KRYZYSIE

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Summary. The real exchange rate is one of the crucial macroeconomic variables for all open economies. Therefore, the 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 to evaluate how relative prices affect the exchange rate. We calculate volatility measures 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 (2002–2007) and the post-crisis period (2009–2015). The results differ substantially between the periods and prove that relative prices play a more important role in explaining the exchange rate behavior in the post-crisis period than in the pre-crisis period.

Key words: real exchange rate, volatility, Granger causality test, variance decomposition, impulse-response function.
Słowa kluczowe: realny kurs walutowy, test przyczynowości Grangera, zmienność, rozkład wariancji, funkcja impuls-reakcja.

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 posed in economic research. The importance of real exchange rate and its monitoring even increased in recent years as a growing share of economic activities is 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 a country's competitiveness in international markets, cross--country comparisons indicate a country's future economic growth and serve as a benchmark for 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 stream 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 Central European member states (Czechia, Hungary, Poland) and three ”old” EU members (Denmark, Sweden, United Kingdom). Hereafter, the countries are denoted as CZ, HU, PL, DK, SE, and UK, respectively.

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):

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

where:

q_t – the real exchange rate,

s_t – the nominal exchange rate,

p_t – the domestic price level and

p_t^* – the foreign price level.

The data were 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 the crisis period (01.2008–06.2009) was excluded from our analysis and the real exchange rates behavior in the pre-crisis and post-crisis period was compared. The pre-crisis period covers 01.2002–12.2007 and the post-crisis period spans from 07.2009 to 06.2015. 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 was computation of volatility. We applied 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, the volatility measure was calculated using the following equation

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

where:

n – the number of quarters. The one-month and three-month volatility indicators were analyzed and the results compared between the periods and across the countries.

Next, our empirical analysis focused on the relationship between the two components of the real exchange rate, i.e. the nominal exchange rate and the relative prices. This analysis was conducted by means of a VAR model. Before setting up the VAR model the long-run stability of the two real exchange rate components was verified with the use of two alternative unit root tests. In particular, the augmented Dickey-Fuller (ADF) and the Phillips-Peron (PP) tests were applied so as to examine stationarity of all series during the pre-crisis and post-crisis periods. Since both tests 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 terms of power (Taguchi 2010).

Due to the application of the VAR model we could consequently use a 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 used 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. Since the Granger causality may not have revealed all of the interactions between the variables of the system, the impulse response function was applied. 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.

REAL EXCHANGE RATES DEVELOPMENT AND VOLATILITY

Before examining volatility of the real exchange rates, it was crucial to look into the evolution of real exchange rates in all analyzed countries. The development in the new EU member states is presented in Fig. 1 and the development in traditional member states in Fig. 2. For graphical convenience, we decided 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 (01.2002–12. 2007), the crisis period (01.2008–06.2009) and the post-crisis period (07.2009–06.2015).

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 by 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 period's start, zloty initially depreciated by 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 relatively stable level. The change of the real exchange rate during the post-crisis period was not remarkably high in none of the countries. Whereas the Polish zloty appreciated by 4%, the Czech koruna and Hungarian forint depreciated by 1% and 3%, respectively.

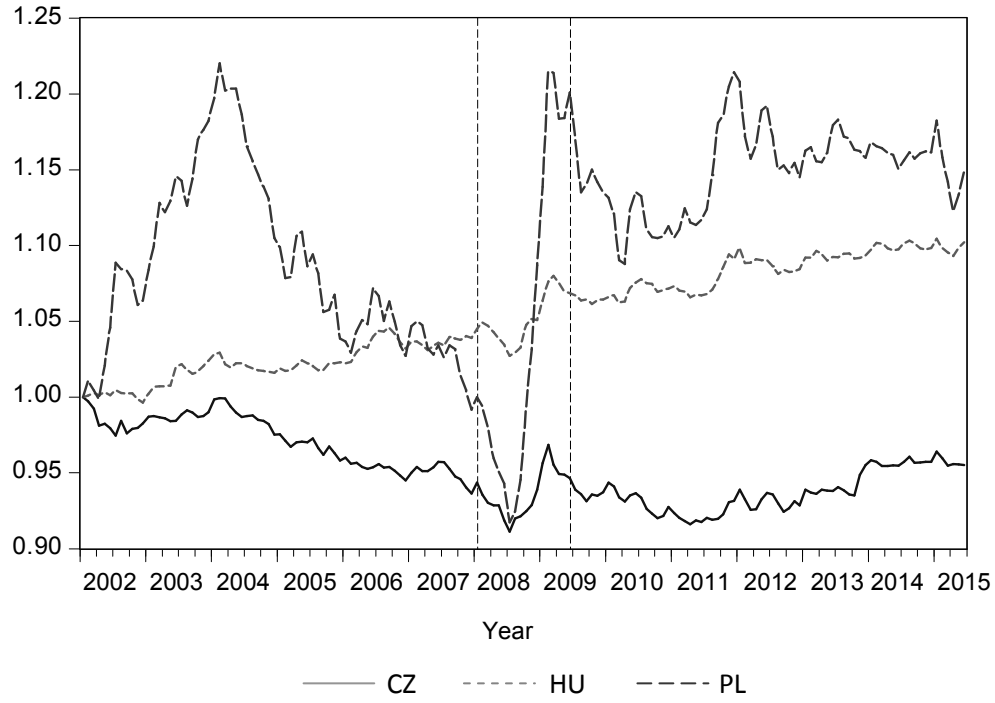

Fig. 1. Real exchange rates evolution in new EU member states (01.2002– 06.2015)
Source: author's calculations based on data from the Eurostat Economy and Finance database (2002–2015).

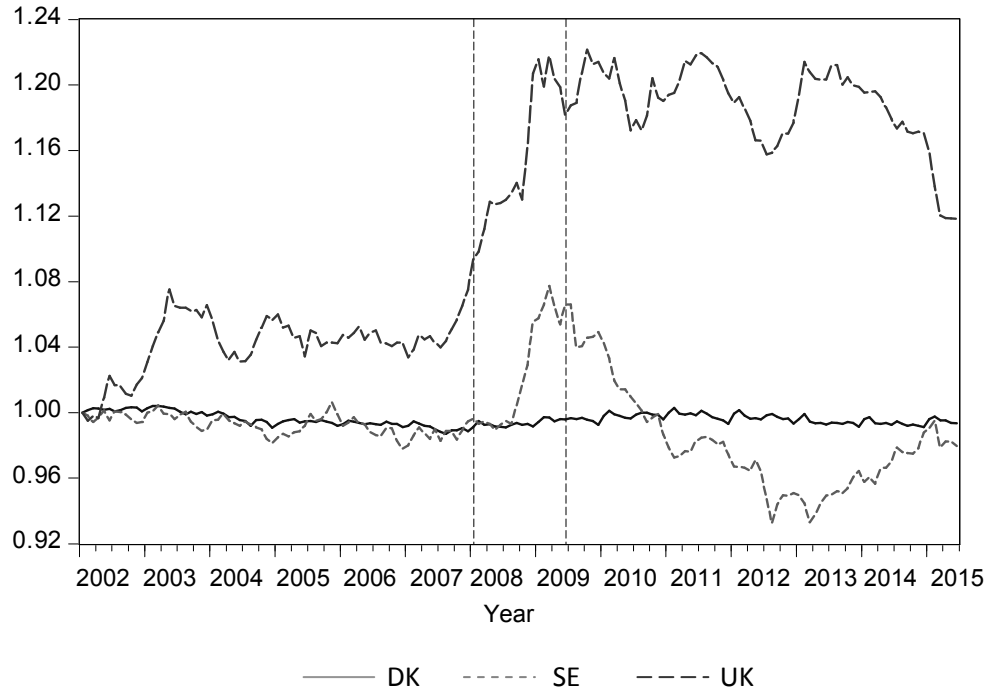

Fig. 2. Real exchange rates evolution in traditional EU member states (01.2002–06.2015)
Source: author's calculations based on data from the Eurostat Economy and Finance database (2002–2015).

When comparing the real exchange rate evolution in the traditional non-eurozone 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 by 1%, Swedish korona appreciated by 0.5%, and British pound depreciated in real terms by 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 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, korona appreciated by 8% during the post-crisis period. The British pound was oscillating around the starting level during the first four years and then embarked on its appreciation path, which resulted in overall appreciation of 5.5%.

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. The volatility of the real exchange rate was computed and analyzed using the measure formulated in (1). Following the approach of Mollick (2009), the volatility indicator was calculated for each exchange rate over three different periods, i.e. the whole period covered by the dataset (01.2002–06.2015), the pre-crisis period and the post-crisis period. Subsequently, the growth rate in volatility between the two sub-periods was computed. 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 09.2015–02.2007 [%]
	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

The results reveal two crucial findings. First, the volatility of the real exchange rate is higher in the new member states than in the traditional members. A substantial difference in volatility between the two groups of countries was identified particularly in the pre-crisis period. The volatility converged significantly during the post-crisis period and the volatility of the Czech koruna real exchange rates became even lower than the Swedish korona and British pound's volatility. Second, the growth rate of volatility between the pre-crisis and post-crisis periods s considerably higher in the group of "old" EU member states than in the new members' group. Similar findings with regard to 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.

INTERACTION BETWEEN THE REAL EXCHANGE RATE COMPONENTS

This section presents the 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 determine the causality between relative prices and exchange rates and the impact of relative prices on exchange rates.

Before conducting all the aforementioned empirical procedures, we tested 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 do reject it in first--differences. This finding is valid 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 proceeded 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**

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

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 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 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 differ across the countries.

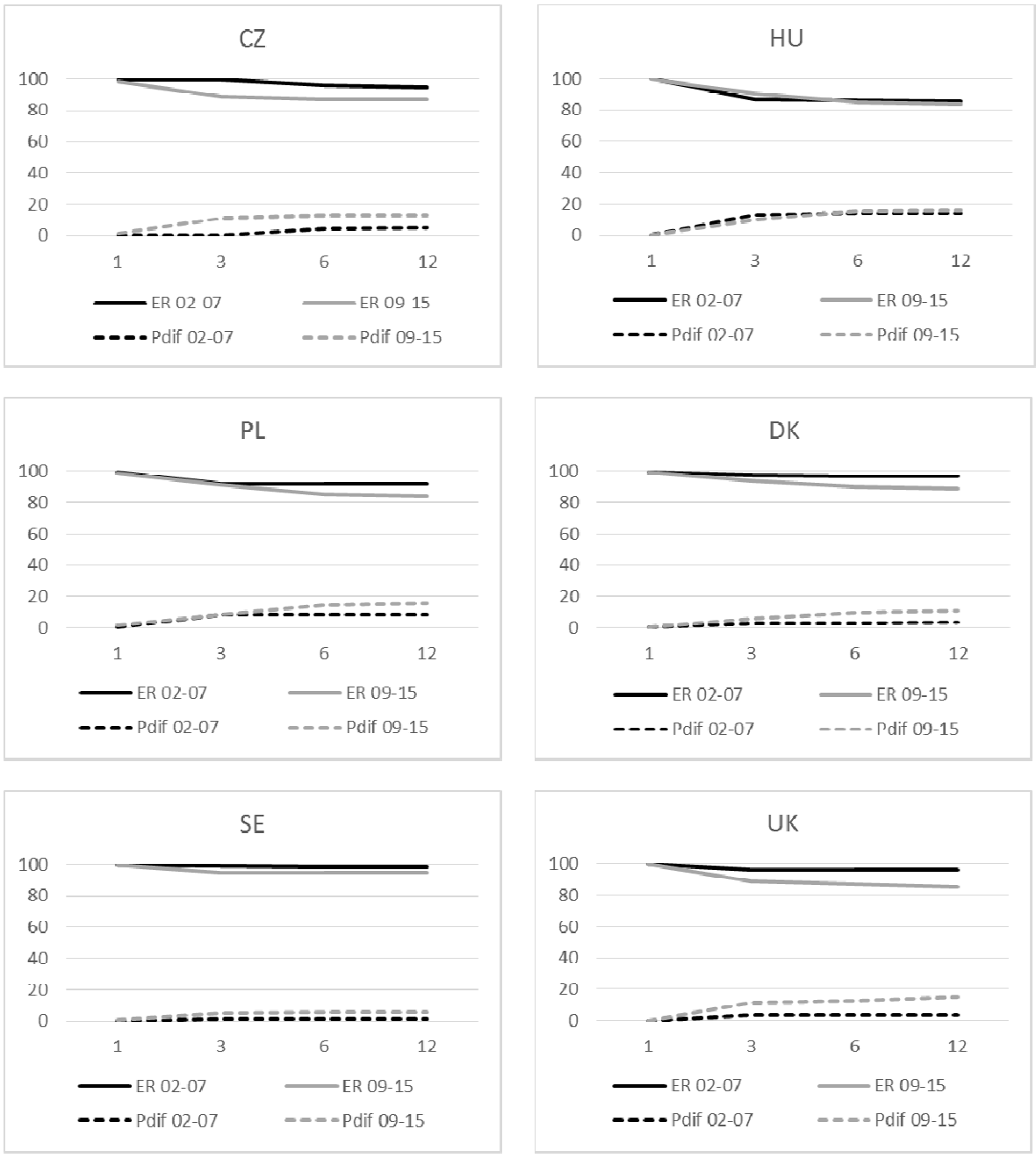

Fig. 3. Variance decomposition in the VAR model. ER – the nominal exchange rate, Pdif – the price differential (relative prices)

The outcome of the variance decomposition analysis is graphically depicted in Fig. 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 relative prices usually grows 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 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 it 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 is 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.

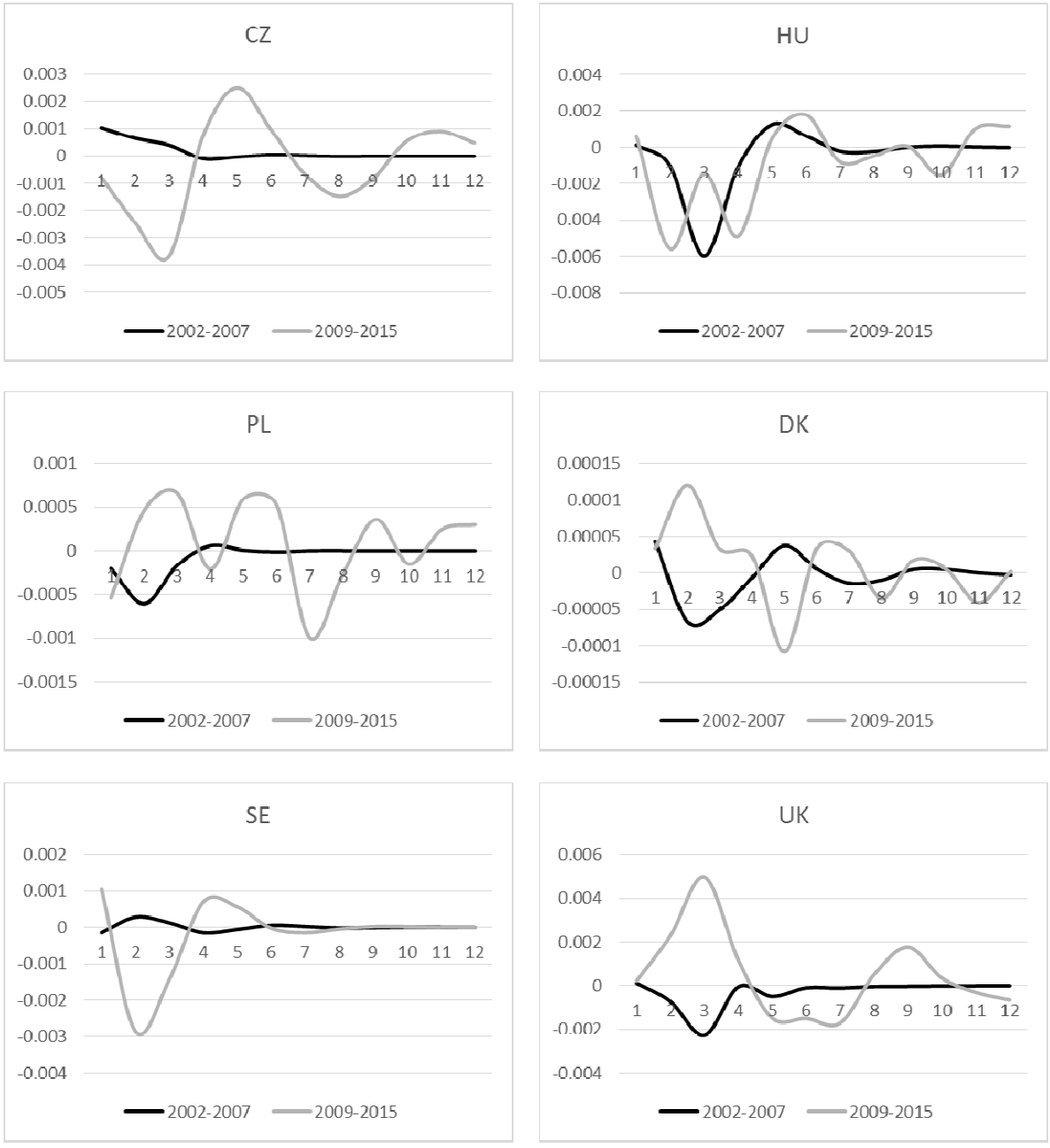

Fig. 4. Impulse-response function of exchange rate to shock in relative prices

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 in 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 valid for almost all currencies. 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 non-negligible values even 12 months after the shock to relative prices.

CONCLUSION

The aim of the paper was to find out whether the causality that the exchange rate movement of exchange rate is influenced by changes in relative prices and to evaluate the impact of relative prices on the exchange rate. The analysis was conducted on a diverse sample of six non-euro EU member states. Since our hypothesis was that the global financial crisis affected the behavior of real exchange rates as well as the interaction among the component variables, all the tests and estimations were conducted for the pre-crisis and post-crisis periods. The crisis period (01.2008–06.2009) 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 about increased volatility in five of the six countries examined, one can identify an uneven effect of the crisis. The post-crisis volatility of real exchange rates in the traditional member states increased remarkably and reached the level typical of the new members. For instance, the one-month and three-month volatility measures in Sweden increased by 70% and 106% between the periods. By contrast, the same indicators in Poland decreased by 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 the economic environment more considerably in the traditional member states and the real exchange rate responded with growing volatility.

The Granger causality test, variance decomposition and impulse-response functions were applied to examine the interaction between the nominal exchange rate and relative prices. Similar to the findings on volatility, it could be observed 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, significantly more cases of Granger causality between the

components of the real exchange rate were identified, including examples where past values of relative prices allowed to predict 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 the 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 the movement of exchange rate is affected by changes in relative prices.

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Streszczenie. Realny kurs walutowy należy kluczowych zmiennych makroekonomicznych we wszystkich gospodarkach otwartych. Dlatego analiza jego ewolucji oraz zmienności i zachowania jego elementów (nominalnego kursu walutowego i cen relatywnych) ma podstawowe znaczenie w teorii ekonomii i w polityce gospodarczej. W artykule skupiono się na interakcji między składnikami realnego kursu walutowego. Głównym celem opracowania jest ocena, w jaki sposób relatywne ceny wpływają na kurs walutowy. Obliczono miary zmienności, użyto testu przyczynowości Grangera, rozkładu wariancji i funkcji impuls–reakcja w modelu Vector Auto Regression dla dla sześciu wybranych państw członkowskich UE spoza strefy EUR (Czech, Węgier, Polski, Danii, Szwecji i Wielkiej Brytanii). Obliczenia prowadzono w dwóch okresach – w okresie przed kryzysem (w latach 2002–2007) i okresie po kryzysie (w latach 2009–2015). Wyniki różnią się znacznie między okresami i dowodzą, że ceny relatywne odgrywają ważniejszą rolę w wyjaśnianiu zachowania kursu walutowego w okresie po kryzysie niż przed nim.