Mendel University in Brno

MENDELU Working Papers in Business and Economics

49/2014

Effective Exchange Rates in Central and Eastern European Countries: Cyclicality and Relationship with Macroeconomic Fundamentals

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Citation

Stavárek, D., Miglietti, C. (2014). Effective Exchange Rates in Central and Eastern European Countries: Cyclicality and Relationship with Macroeconomic Fundamentals. *MENDELU Working Papers in Business and Economics* 49/2014. Mendel University in Brno. Cited from: http://ideas.repec.org/s/men/wpaper.html

Abstract

Daniel Stavárek, Cynthia Miglietti: **Effective Exchange Rates in Central and Eastern European Countries: Cyclicality and Relationship with Macroeconomic Fundamentals**

This paper provides direct empirical evidence on the nature of the relationship between effective exchange rates and selected macroeconomic fundamentals in nine central and Eastern European countries. Therefore, the paper addresses a key precondition of numerous exchange rate determination models and theories that will explain the role of exchange rates in the economy. Additionaly, short-term volatility and medium-term variability of effective exchange rates are examined. The results suggest that flexible exchange rate arrangements are reflected in higher volatility and variability of nominal as well as real effective exchange rates. Furthermore, the results provide mixed evidence in intensity, direction and cyclicality but show a weak correlation between exchange rates and fundamentals. Sufficiently high coefficients are found only for the money supply. Consequently, using fundamentals for the determination of exchange rates and using the exchange rate for an explanation of economic development can be limited for the countries analyzed.

Key words

effective exchange rates, volatility, variability, cycle, high/low analysis, peak/trough analysis, cross correlation

JEL: E32, E44, F31

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Acknowledgements

The research behind this paper was supported by the Czech Science Foundation within the project GAČR 13-03783S “Banking Sector and Monetary Policy: Lessons from New EU Countries after Ten Years of Membership”. This support is tremendously acknowledged.

Introduction

Since the collapse of the Bretton Woods system in the 1970s and introduction of the floating exchange rates that followed, there has been a continuing debate on whether and how exchange rates are related to economic fundamentals. In literature, one can find an enourmous number of models that have been proposed during the floating rate period and which assume an influence of various macroeconomic variables on exchange rates. Many studies have been published that show an empirical application of the models and that aim to explain exchange rate behavior and/or to predict future exchange rate development. The most influential and widely used models from that period are based on principles of purchasing power parity and interest rate parity or that belong to the class of monetary models of exchange rate determination (Cheung et al., 2005). We can use the monetary models as an example of a conventional set of fundamentals that are usually applied. The fundamentals shared by all models from this class include differentials in money supply, output in the form of gross domestic product or income, long-term interest rate, inflation rate and trade balance (Dal Bianco et al., 2012).

However, Meese and Rogoff (1983) found that fundamentals-based exchange rate models fail to outperform random-walk models. Additionally, De Grauwe and Grimaldi (2006) and other researchers provide more recent evidence that the relationship between exchange rates and macroeconomic variables is rarely supported by real data and the respective models often fail empirically. The missing relationship between exchange rates and macroeconomic aggregates is labeled as "exchange rate disconnect puzzle" and is one of the six major puzzles in international economics described by Obstfeld and Rogoff (2001). As Jindrová (2007) points out the exchange rate disconnect puzzle consists of two different phenomena. The first refers to the exchange rate determination puzzle and draws from the previously mentioned findings by Meese and Rogoff (1983). The second part of the puzzle refers to extreme (excessive) volatility of exchange rates with respect to other macroeconomic fundamentals. There is also evidence that business cycle properties of macroeconomic aggregates are only slightly affected by the exchange rate regime applied (Dedola and Leluc, 2001).

The interaction between exchange rates and macroeconomic variables can also be examined from the opposite perspective, i.e. how exchange rates affect the fundamentals and overall economy. Moreover, one should take into account that exchange rates can matter both in terms of their level and volatility.

One of the major channels through which the exchange rate affects economic conditions is through their impact on prices. The effect occurs either directly through import prices or indirectly through the impact of price changes on real incomes, customer spending and trade flows, with feedback effects on overall price level. The second key role that exchange rate plays in economy is the impact on international trade flows through the expenditure-switching effect. An appreciation of domestic currency implies a reduction in exports and an increase in imports resulting in an overall deterioration in the trade balance and thus a reduction in the contribution of net trade to GDP growth. The third crucial channel through which exchange rates influence the economy is through their effect on total volume of foreign direct investment that takes place and the allocation of investment spending acorss a range of countries. When a currency appreciates, it increases that country's wages and production costs relative to those of its foreign counterparts. If all else is equal, the attractiveness of the country experiencing real appreciation has worsened and the country is likely to receive less productive capacity investment.

Many researchers have tested for those effects empirically in a broad spectrum of countries and time periods. However, the evidence provided by the studies is rather mixed and the effects of exchange rates on the economy have often been found as insignificant. For instance, Di Mauro et al. (2008) analyzed the changing role of exchange rates in the global economy of the euro area. They concluded that both the pass-through effect of exchange rates on prices and exports have declined as a result of globalization. Furthermore, ambiguous findings on exchange rate effects were reported by An and Wang (2012), Hoffmann and Holtemöller (2010) and others.

This paper is written to respond to the inconsistencies between a strong theoretical foundation for the relationship between exchange rates and macroeconomic fundamentals and the weak results obtained in empirical studies. The main objective of the paper is to identify the nature of the relationship in selected Central and Eastern European countries (CEEC). In addition to providing direct empirical evidence on the relationship between effective exchange rates and a number of fundamentals we evaluated the short-term volatility and medium-term variability of the exchange rates. We worked with data for a group of nine CEEC that consisted of Bulgaria (BUL), Czechia (CZE), Estonia (EST), Hungary (HUN), Latvia (LAT), Lithuania (LIT), Poland (POL), Slovenia (SLO) and Slovakia (SVK). All of the countries are members of the European Union (EU). Eight of the countries joined the EU in May 2004. Bulgaria became an EU member state in January 2007. Romania was excluded from the dataset due to the irregularity of the available data.

It is critically important to note what is not studied and thus not reported in the paper. We neither evaluate the relevance of macroeconomic aggregates in exchange rate determination nor attempt to predict exchange rate development or estimate the effect of exchange rates on the economy. In empirical estimation, we consider the business cycle and cyclical properties of the variables which will enhance the credibility of our results. This kind of research is motivated by several factors. First, very few studies have been published for the new EU member states. Second, our goal is to expand the current knowledge on the topic by using effective exchange rates rather than bilateral to better reflect the real economic environment in which countries interact with each other. Third, according to economic theory, the development of exchange rates is particularly important to an open economy such as that of the CEEC. Fourth, with the current very low (almost zero) interest rates, the exchange rates have been used as a standard monetary policy tool by many central banks. Therefore, the relevance of this subject for policy-making has greatly increased.

The paper has three sections. In the first section, we describe the evolution of the effective exchange rates in the CEEC. We apply various techniques to examine short-term volatility, medium-term variability and phases of the development cycles. In Section 2, we introduce the dataset and empirical methods used for assessing the cyclical relationship between exchange rates and selected macroeconomic aggregates. The results of the cross correlation between exchange rates and macroeconomic aggregates are reported and discussed in Section 3. In the conclusion of the paper, we report the summary of main findings and implications.

1 Stylized facts on effective exchange rates

In this section, we examine several aspects of the development of effective exchange rates in the CEEC. An effective exchange rate can be defined as a measure of one economy's currency against a basket of foreign currencies. Each currency in the basket gains a specific weight based on international trade patterns. The effective exchange rate can be calculated in nominal and real terms. The real effective exchange rate (REER) differs from the nominal effective exchange rate (NEER) because it is adjusted for the domestic price level relative to price levels in other foreign countries. Since all of the CEEC that were analyzed are open economies of relatively small size, they are heavily involved in international trade and capital flow, and have international economic activities with many foreign countries. Thus, we used effective rather than bilateral exchange rates because the former measure captures the role of exchange rates in the economy more comprehensively and reliably.

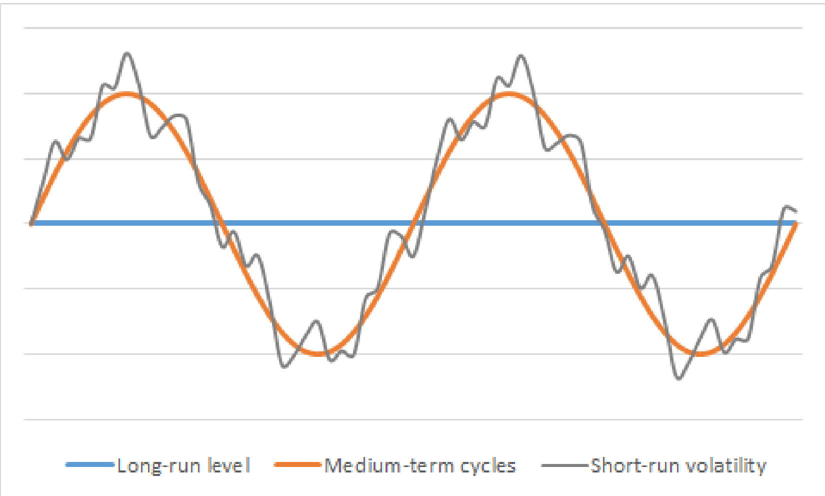
The behavior of effective exchange rates can be analyzed using three time horizons. One should distinguish between them as they all differ in determinants, characteristic features and policy implications. According to Mabin (2010) and depicted in Figure 1, the three approaches to the effective exchange rates are as follows:

- Long-run level which can represent an average or equilibrium exchange rate. This long-run level can be constant over time or can show a trend of long-term continuous appreciation or depreciation of a domestic currency.

- Medium-term cycles or swings which reflect deviations from the long-run equilibrium level. The length of the cycle can be several years and we refer them to as exchange rate variability.

- Short-term volatility can reflect a month-to-month change in effective exchange rates up to a maximum of one year. We can observe them as 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.

Figure 1: Stylized path of the evolution of effective exchange rates



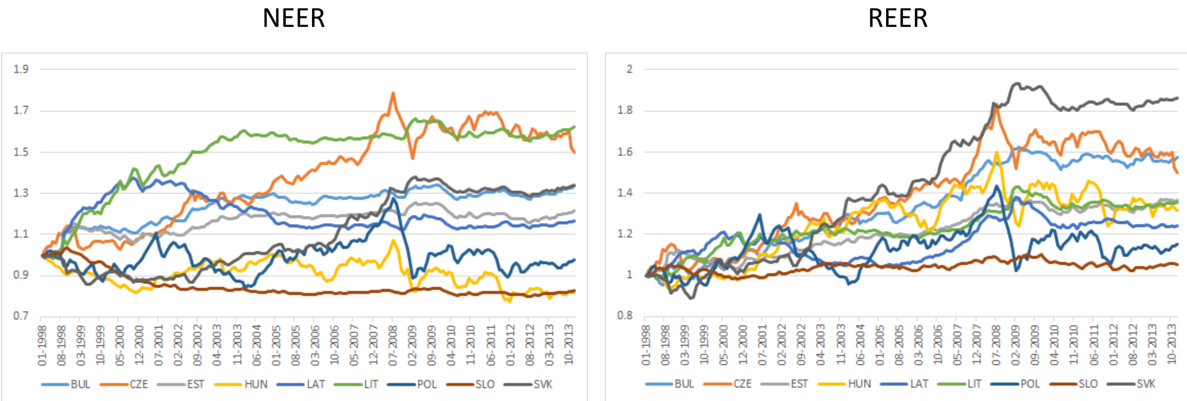
Source: Authors' adaptation based on Mabin (2010, p. 5)

Next, we will introduce the evolution of effective exchange rate indices in the CEEC during the period under examination. In addition, we will explain the development of the exchange rate arrangements applied in the CEEC. Then we will focus on two aspects of the exchange rate development, the short-run volatility and medium-term cycles present in the nominal and real effective exchange rates, as described above.

1.1 Evolution of effective exchange rates in the context of exchange rate regime

Since the entire analysis conducted for and reported in this paper is based on effective exchanges, it is necessary to present and briefly discuss the evolution of NEER and REER for the CEEC that are examined. Figure 2 shows the evolution of these two indices over a period of 14 years. It is evident that the CEEC followed very different development paths particularly in the case of NEER. During the first five years of the examined period the gap between the most appreciated (Lithuanian litas) and most depreciated currency (Slovenian tolar) expanded to almost 70 percentage points. Since that time general conditions have not changed significantly and we were able to distinguish three groups of countries. The first group consists of Lithuania and Czechia whose currencies achieved the largest nominal effective appreciation of 62.3% and 50.1% respectively. By contrast, the second group is composed of Hungary, Slovenia and Poland whose currencies depreciated over the 14 years and the exchange rate value at the end of 2013 was weaker by 18.4%, 17.3% and 3.2% respectively than the starting value in January 1998. The third group includes Slovakia, Bulgaria, Estonia and Latvia whose currencies maintained a nominal effective appreciation of approximately 20% over the period.

Figure 2: NEER and REER evolution in the CEEC (1998-2013)



Note: An increase of the exchange rate represents an appreciation of the currency. The exchange rate indices cover 61 partner economies.
Source: Authors' calculations based on data from the Bank for International Settlements

The evolution of REER seemed to be more homogeneous across the CEE region over the first five years of the period under examination. All the currencies shared a common trend of real appreciation and the rate achieved was approximately 15%. While this trend generally continued after 2002, the pace of appreciation started to differ between the countries. The fastest real appreciation during the pre-crisis period was experienced by Slovakia and Czechia followed by Hungary and Bulgaria. In July 2008, the rate of appreciation as compared to January 1998 reached almost 85% in Slovakia and 80% in Czechia. The Hungarian and Bulgarian currencies appreciated by

60% and 55% respectively during the same years. Real appreciation in effective terms reached about 30% in all of the Baltic States but less than 10% in Slovenia. In the post-crisis period, it can be seen that the REER for all countries did not change because the exchange rates stabilized on the levels that emerged after the culmination of the volatile crisis period.

Table 1: Overview of exchange rate arrangements applied in the CEEC

Bulgaria		managed floating	currency board		
Czech Republic	peg with horizontal bands	managed floating			
Estonia		currency board	ERM2	eurozone	
Hungary	adjustable peg	crawling peg	peg with horizontal bands	managed floating	
Latvia		floating	conventional fixed peg	ERM2	
Lithuania		floating	currency board	ERM2	
Poland		crawling peg	free floating		
Romania	free floating	managed floating			
Slovak Republic	peg with horizontal bands	managed floating	ERM2	eurozone	
Slovenia		managed floating	crawling band	ERM2	eurozone
	1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013				

Source: Mirdala (2013, p. 470)

Many aspects of the effective exchange rate development can be fully or partially explained by the applied exchange rate arrangement. The CEEC have been using various regimes and the sequential application of three and more arrangements since the start of economic transformation as can be seen in Table 1. For example, one can notice a substantially increased volatility of NEER as well as REER in Czechia, Poland and Hungary during the crisis period. These sharp ups and downs within a short period of time distinguish these countries from the rest of CEE region. Not surprisingly only those three countries still had their own national currency and followed some form of floating exchange rate regime at that time.

Interestingly, Table 1 shows a considerable diversity in exchange rate regimes among the countries. However, one can identify several groupings of countries that have followed a similar strategy in exchange rate policy. Small Baltic countries preferred a fixed arrangement from the very beginning of the transformation process in the early 1990s. Estonia and Lithuania adopted currency board regime while Latvia followed a conventional fixed peg arrangement. The inclination toward a fixed exchange rate in the Baltic States persisted over the entire period analyzed or was replaced by a membership in the euro area (Estonia in 2011, Latvia in 2014) and the obligatory participation in the Exchange Rate Mechanism II (ERM II).

Even though Czechia, Hungary, Poland and Slovakia embarked on a path of transformation with a fixed or semi-fixed exchange rate regime in the form of peg with horizontal bands or crawling peg, they switched to a managed or free floating arrangement after facing a monetary crisis and/or completion of most of the transformation process. However, Slovakia planned to join the euro area and replaced the national currency with the euro in 2009. Due to a low level of reserves and despite high inflation rates, Bulgaria and Slovenia first adopted a managed floating arrangement and then moved to a less flexible exchange rate regime. Bulgaria implemented a currency board due to lack of credibility and Slovenia adopted a crawling band followed by a strategy of expedited membership in the euro area. When interpreting the evolution of NEER and REER in the CEEC we have to take into consideration the differences in the applied exchange rate regime and be conscious of the fact that deviations of REER in countries with a fixed arrangement are mainly driven by changes in relative price levels.

1.2 Volatility of effective exchange rates

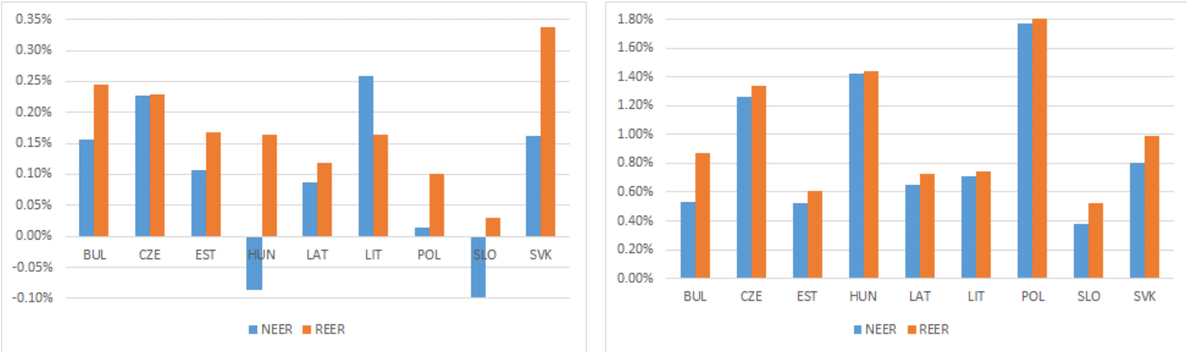
This section of the paper is focused on the short-term volatility of NEER and REER. Accordingly, we calculated monthly changes of the exchange rate measures and computed a simple average of the changes over the entire estimation period. In Figure 3, we present the means of changes (left graph) and means of absolute changes (right graph). Whereas the average of monthly changes demonstrates mainly the prevalence of positive or negative movements of the exchange rates, the average of absolute changes illustrates the volatility. Additionally, another standard indicator of volatility that we calculated is the standard deviation. While the results of this measure are different from the averages, the standings of the countries and the interpretation of the results remain the same.

The diverse evolution of NEER depicted in Figure 2 is reflected in the means of monthly changes as can be seen in Figure 3. The countries that went through nominal depreciation display negative average figures or a value close to zero. Conversely, the countries with the largest rate of nominal appreciation exhibit the highest positive averages of monthly changes. Nevertheless, when assessing the short-term volatility of the effective exchange rates, we should be focused primarily on the averages of absolute monthly changes.

Figure 3: Effective exchange rates volatility (1998-2013)

Average of monthly changes

Average of absolute monthly changes



Source: Authors' calculations based on data from the Bank for International Settlements

Two important findings can be observed in Figure 3. First, the short-term volatility of REER is higher than the volatility of NEER in all examined countries. Apparently, changes in relative price levels in CEEC in relation to other trading partners usually support changes in NEER and make the REER movements more sizeable. This finding is also obvious in countries that are part of the monetary union or that fix the national currency against another currency. In this instance, an economy can only achieve stability against that currency which will fluctuate against other currencies. Additionally, the real exchange rate is influenced by relative price movements which depend on a range of factors that cannot be controlled even in a country with a fixed regime.

The second finding is that the countries that have been using a floating regime over most of the analyzed period and during the turbulent crisis times definitely show higher exchange rate volatility than the countries with fixed regimes. The most volatile effective exchange rates were revealed for Poland (free floating) and Czechia (managed floating) and Hungary (managed floating in combination with peg with wide fluctuation bands). Conversely, the lowest levels of volatility were found in Slovenia and Estonia.

1.3 Cycles in effective exchange rates development

Although an economy may have a volatile currency and exchange rate on a short-term basis, this need not necessarily result in large exchange rate cycles. We applied two measures to assess the medium-term variability of effective exchange rates and to identify cycles in the exchange rate development. The first is a high/low analysis over the whole exchange rate time series. It shows the range between the maximum and minimum value of the exchange rate and indicates the span of the exchange range variability. The ranges are delineated in Figure 4 for NEER as well as REER. The graphs are supplemented by values of average and median exchange rate. The last value in the exchange rate time series is from December 2013.

Figure 4: Effective exchange rates variability – high/low analysis (1998-2013)

Note: The range is the difference between the highest and lowest exchange rate over the examined period calculated as Range = (max – min)/min. The average, median and end figures are presented in percentage form relative to the minimum value of the exchange rate series. The end figure refers to December 2013.
Source: Authors' calculations based on data from the Bank for International Settlements

The results suggest that the variability of exchange rates differs for NEER and REER for all of the countries studied. While the most variable NEER can be found in Czechia with the range of about 79% followed by Lithuania (69%) and Slovakia (61%) the most variable REER was revealed in Slovakia (118%), Czechia (83%) and Bulgaria along with Hungary (70%). By contrast, the least variable exchange rates in both measures were identified in Estonia (26% for NEER and 37% for REER) and in Slovenia (29% for NEER and 12% for REER). These findings closely correspond to the short-term volatility measured by the average of absolute monthly changes. For most of the countries, the variability range seems to be balanced as the average and median values are situated in the middle of the range. Regarding the exchange rates in December 2013, one can conclude that the most recent exchange rate levels certainly represent neither a peak nor a trough in any of the "floating" countries. On the other hand, the recent figures of NEER and REER in Bulgaria, Lithuania or Slovakia were very close to the historical highs. This finding confirms that the exchange rate in countries with an independent national currency and floating exchange rate regime can absorb a portion of a macroeconomic shock such as the financial crisis followed by recession more easily than countries with fixed regimes or members of the euro area.

While being a relatively simple indicator, the high/low analysis provides evidence of the variability of individual exchange rates when compared internationally. However, the high/low approach cannot be effectively applied as a measure of variability and cycles if a series exhibits a structural change in development. Furthermore, the high/low analysis can miss important information about the size of different cycles, and can be influenced by changes in the equilibrium levels of exchange rates. Therefore, Mabin (2010) recommends application of the high/low analysis in conjunction with a more robust peak/trough analysis.

Figure 5: Effective exchange rates variability – peak/trough analysis (1998-2013)

Note: The amplitude is generally calculated as a difference between consecutive peak (trough) and trough (peak) divided by the midpoint between the peak and trough. The reported figure of amplitude (left axis) is the average of all computed amplitudes for the respective currency over the period of examination. The monthly amplitude (right axis) is the mean of average monthly amplitudes of all identified peak/trough cycles. The weighted monthly amplitude (right axis) reflects the length of the cycle and assigns higher weight to longer cycles.
Source: Authors' calculations based on data from the Bank for International Settlements

The peak/trough analysis definitely captures more information about the medium-term variability than the high/low analysis. However, it suffers from one serious drawback as there are no hard-and-fast rules used for identification of peaks and troughs of the cycle. The peaks and troughs are determined by the individual researcher. Therefore, one can find numerous techniques and procedures of how to define the turning points of cycles. We have used two generally accepted rules for the identification of peaks and troughs. First, the distance between two consecutive peaks (troughs) should be at least 30 months. Second, each phase of the cycle (peak-to-trough or trough-to-peak) should be no less than six months. After application of this approach we obtained results about the amplitude of the exchange rate cycles. The results are reported in Figure 5. Our approach for detecting the peaks and troughs does differ from the method used in Schmidt-Hebbel (2006) that would have generated many small phases within a short-term horizon.

When we compare the results of the peak/trough and high/low analyses, we find that they are not similar. In addition, the conclusions about which economies operate with the most variable effective exchange rates differ. As far as NEER is concerned, the highest variability was found in Poland, Hungary and Slovakia while the lowest average amplitude was in Slovenia, Bulgaria and Estonia. If we take REER into consideration the most variable exchange rate was in Slovakia followed by Bulgaria and Poland and the least variable exchange rate was computed for Lithuania, Estonia and Slovenia. The figures of average amplitude generally correspond with values of the average monthly and average weighted monthly amplitudes. We can observe that a high average amplitude is usually closely associated with high monthly amplitudes and vice versa. The only exceptions are REER in Bulgaria and Slovakia. In these time series, we determined that there were only a few long and ample phases of the cycle (three phases in Bulgaria and four phases in Slovakia), which naturally makes the average amplitude relatively high and monthly amplitudes relatively low.

The detailed information on effective exchange rate cycles is presented in Table 2. In the table, we report the mean duration of the phase, average amplitude and cumulative exchange rate change separately for the peak-to-trough and trough-to-peak phases. We also indicate how many times the respective cycle phase occurred during the entire period of estimation.

As a result of our computations, we can disseminate two general conclusions on the effective exchange rates cycles. First, the peak-to-trough phase is usually shorter than the trough-to-peak phase of the cycle. The exceptions to this rule are both exchange rate indices in Slovenia and NEER in Latvia. Second, a corresponding conclusion can be drawn from the figures of the mean amplitude of the phase. The average amplitude of the peak-to-trough phase is commonly lower than the trough-to-peak amplitude. This rule holds true in 16 out of 18 cases (not for NEER in Hungary and Slovenia).

In addition to the general conclusions, we can also compare national characteristics of the exchange rate cycles. The longest average downward phase of the cycle was identified in Slovenia (56.5 months for NEER and 32 months for REER). While the longest peak-to-trough phase in NEER also occurred in Slovenia (80 months), the longest decline in REER was revealed in Bulgaria (39 months). Conversely, the shortest average peak-to-trough phase in NEER was found in Estonia (10.8 months) and in Czechia for REER (11.2 months). The shortest downward phase of the cycles was 6 months and was discovered in multiple cases across the CEEC.

Table 2: Amplitude and duration of effective exchange rate cycles (1998-2013)

	Bulgaria		Czechia		Estonia	
	NEER	REER	NEER	REER	NEER	REER
	Peak-to-trough					
Number of occurrences	3	1	5	5	6	4
Mean duration (months)	25.3	39.0	12.8	11.2	10.8	14.5
Mean amplitude (%)	3.36%	6.01%	10.00%	10.07%	3.79%	4.11%
Cumulative change (%)	10.07%	6.01%	49.99%	50.33%	22.72%	16.44%
	Trough-to-peak					
Number of occurrences	2	2	5	4	6	3
Mean duration (months)	43.5	68.0	23.2	31.5	18.0	35.0
Mean amplitude (%)	10.61%	28.00%	16.82%	19.14%	6.28%	10.58%
Cumulative change (%)	21.23%	55.99%	84.11%	76.56%	37.68%	31.74%
	Hungary		Latvia		Lithuania	
	NEER	REER	NEER	REER	NEER	REER
	Peak-to-trough					
Number of occurrences	5	4	3	4	3	3
Mean duration (months)	18.4	14.0	31.0	16.0	20.7	20.3
Mean amplitude (%)	16.26%	14.61%	8.77%	7.85%	3.66%	4.86%
Cumulative change (%)	81.30%	58.43%	26.31%	31.41%	10.97%	14.58%
	Trough-to-peak					
Number of occurrences	4	5	3	4	3	3
Mean duration (months)	20.3	22.0	26.3	28.0	36.3	35.0
Mean amplitude (%)	14.95%	19.24%	13.32%	13.32%	18.56%	14.77%
Cumulative change (%)	59.82%	96.22%	39.97%	53.29%	55.69%	44.30%
	Poland		Slovenia		Slovakia	
	NEER	REER	NEER	REER	NEER	REER
	Peak-to-trough					
Number of occurrences	4	5	2	3	3	2
Mean duration (months)	21.3	17.6	56.5	32.0	19.7	16.5
Mean amplitude (%)	23.13%	15.35%	14.40%	5.92%	9.41%	8.81%
Cumulative change (%)	92.51%	76.75%	28.81%	17.75%	28.23%	17.62%
	Trough-to-peak					
Number of occurrences	3	4	3	3	3	2
Mean duration (months)	28.3	23.8	25.3	28.0	42.7	77.0
Mean amplitude (%)	27.10%	20.64%	3.47%	6.10%	19.17%	38.02%
Cumulative change (%)	81.30%	82.57%	10.40%	18.31%	57.50%	76.05%

Source: Authors’ calculations based on data from the Bank for International Settlements

Regarding the trough-to-peak phase of the cycle, we can summarize that the longest average phase was identified in Bulgaria for NEER (43.5 months) and in Slovakia for REER (77 months). The same countries also experienced the longest upward phases. However, the indices are reversed when compared to average figures. The longest trough-to-peak NEER phase occurred in Slovakia (101 months) and the longest phase in REER was found in Bulgaria (128 months). The shortest average duration of the trough-to-peak phase in NEER was calculated for Estonia (18 months) and in REER for Hungary (22 months). The shortest upward phase of the cycle lasted 7 months and occurred several times in various countries.

2 Data and methodology for analysis of the cyclical relationship between exchange rates and macroeconomic fundamentals

The data gathered consist of the quarterly gross domestic product (GDP), long-term interest rates represented by 10-year government bond yields, inflow of foreign direct and portfolio investment, the money supply expressed as the M2 monetary aggregate, and nominal and real effective exchange rates (NEER and REER) over the period from January 1998 to December 2013. Earlier data are available for some of the countries but we preferred to work with a consistent dataset that excludes observations from turbulent years during the 1990s. The data during the time period are in national currencies, market prices and are seasonally adjusted. The effective exchange rate series used in this part of the paper are composed of 37 main trading partners. The Eurostat database was used for all of the data collected on the economy and finance and the time series of investment inflow was obtained from the databases of national central banks.

We converted all of the series into logs and used the Hodrick-Prescott filter (HP filter) to obtain a cyclical component for each time series. Then, we applied cross correlation to all of the combinations of changes in the cyclical component of NEER resp. REER and macroeconomic variable.

An unobservable time trend for time series variables is estimated using the HP filter. This filter is used to obtain a smoothed-curve representation of a time series, one that is more sensitive to long-term than to short-term fluctuations. Hodrick and Prescott first introduced the procedure in 1980 for estimating business cycles. Interestingly, their paper (Hodrick and Prescott, 1997) was published 17 years later after the filter had been widely used in macroeconomics. An observable macroeconomic time series will be denoted by y_t. Using the HP filter, then y_t decomposes into a nonstationary trend g_t and a stationary residual cyclical component c_t which gives the following formula:

(1) $$y_t = g_t + c_t.$$

It should be noted that g_t and c_t are not able to be observed. This means that since c_t is a stationary process we can think of y_t as a noisy signal for the nonstationary trend g_t. Thus, the problem condenses down to how to extract an estimate for g_t from data on y_t.

This problem is solved by use of the HP filter which allocates some weight to a linear trend against the signal y_t. That weight is represented by λ. If there is no noise then the signal is fully informative and λ is set to zero. As λ increases more weight is given to the linear trend, and for $\lambda \to \infty$, g_t approaches the ordinary least squares estimate of y_t against a linear time trend. From their research, Hodrick and Prescott found that if c_t and the second difference of g_t, $\Delta\Delta g_t$, are identically and independently distributed normal variables with mean zero and variances $\sigma^2_{c_t}$ and $\sigma^2_{\Delta\Delta g_t}$, then the best choice of λ is $\frac{\sigma^2_{c_t}}{\sigma^2_{\Delta\Delta g_t}}$. In general, data in high frequency are noisier relative to low frequency data series. Therefore, high frequency data require a higher value of λ. For quarterly data, Hodrick and Prescott advised that using a value of λ = 1600 is reasonable. Assuming an adequately chosen, positive value of λ, there is a trend component that will minimize:

(2) $$\min_{\{g_t\}_{t=1}^{T}} \sum_{t=1}^{T}(y_t - g_t)^2 + \lambda \sum_{t=2}^{T-1}\left[(g_{t+1} - g_t) - (g_t - g_{t-1})\right]^2$$

The equation's first term is the sum of the squared deviations which imposes a penalty on the variance of cyclical component. The second term is a multiple λ of the sum of the squares of the trend component's second differences. It also penalizes variations in the growth rate (lack of smoothness) of the trend component. This means that the larger the value of λ, the higher the penalty. Specifically, the HP filter identifies the cyclical component c_t from y_t by the trade-off to the extent which the trend component keeps track of the original series y_t (good fit) in relation to the prescribed smoothness in the trend component g_t.

The use of cross correlation is a standard method for estimating the degree to which two series are correlated. It assesses how one reference time series correlates with another time series as a function of time shift (lag). This method does not yield a single correlation coefficient but rather an entire series of correlation values. A whole series of correlation coefficients is achieved by shifting one of the series forward and backward in time. Cross correlation is significant when studying the relationship between time series for two reasons. The first is because one series may have a delayed response to the other series, or perhaps a delayed response to a common stimulus that affects both series. Secondly, the response of one series to another series or an outside stimulus may be "smeared" in time, such that a stimulus restricted to one observation elicits a response at multiple observations. Analogous to all correlations, cross correlation will show only statistical associations not causation. Therefore, we cannot say that changes in one time series will cause changes in the other, but the two series behave as if this were the case.

When we examine two financial series x_t and y_t, it can be seen that the cross-correlation at lag (lead) *k* is defined as follows:

$$(3) \qquad \rho(y_{t+k}, x_t) = \frac{\text{cov}(y_{t+k}, x_t)}{\sqrt{V(y_{t+k})}\sqrt{V(x_t)}} = \frac{T\sum_{t=k-1}^{T}(y_{t+k} - m_y)(x_t - m_x)}{(T+k)\sqrt{\sum_{t=k}^{T}(y_{t+k} - m_y)^2}\sqrt{\sum_{t=k}^{T}(x_t - m_x)^2}}$$

where ρ is the correlation coefficient and m_x and m_y are the means of the corresponding series. It should be noted that the series can be related in three possible ways: (i) y_t can lead x_t ($\rho(y_{t-k}, x_t) \neq 0$), (ii) y_t can lag x_t ($\rho(y_{t+k}, x_t) \neq 0$), (iii) series can be contemporaneously related ($\rho(y_t, x_t) \neq 0$).

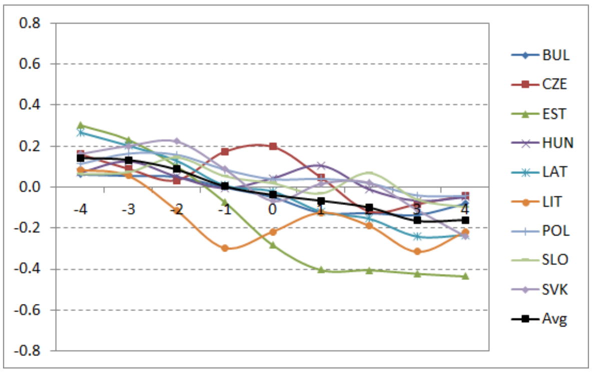
3 Cross correlation between exchange rates and macroeconomic fundamentals

We expanded the research completed by Duarte et al. (2007) and Stavárek (2013) by running cross correlations for all eight possible combinations of exchange rates and macroeconomic fundamentals for each country. Consequently, we applied a time shift of up to four lags (leads) on the time series of exchange rate cycles relative to the cycle in the macroeconomic fundamental variable. Thus, we can say that the exchange rate leads the fundamental (fundamental lags the exchange rate) by *k* quarters if $|\rho(y_{t+k}, x_t)|$ is a maximum for a negative *k*, the exchange rate is synchronous with the fundamental if $|\rho(y_{t+k}, x_t)|$ is a maximum for *k* = 0, and the exchange rate lags the fundamental (fundamental leads the exchange rate) if $|\rho(y_{t+k}, x_t)|$ is a maximum for a positive *k*. Presented in Figure 6 are the correlation coefficients that were obtained from this analysis. As can be seen from the figure, we reported cross correlations for all countries as well as the average value for the entire group.

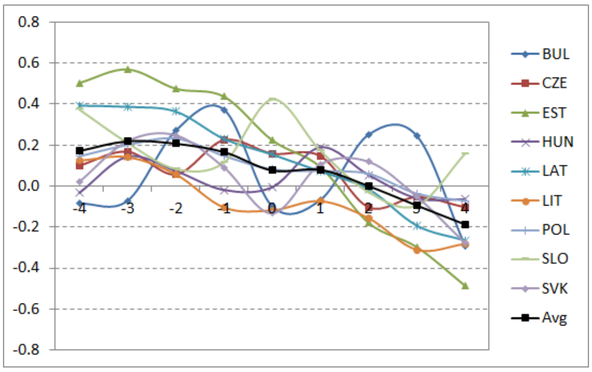
The analysis of cross correlations was completed based on the work of Rand and Tarp (2002). We defined the exchange rate as procyclical, acyclical, or countercyclical depending on whether the respective correlation coefficient is positive, zero, or negative. Additionally, we deemed the exchange rate to be strongly correlated if $0.26 \leq |\rho(y_{t+k}, x_t)| \leq 1$, weakly correlated if $0.13 \leq |\rho(y_{t+k}, x_t)| < 0.26$ and uncorrelated if $0 \leq |\rho(y_{t+k}, x_t)| < 0.13$.

Figure 6: Cross correlation between macroeconomic fundamentals and exchange rates

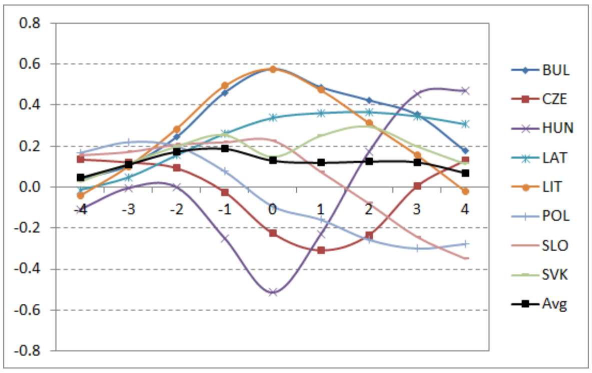
GDP$_t$ – NEER$_{t+k}$



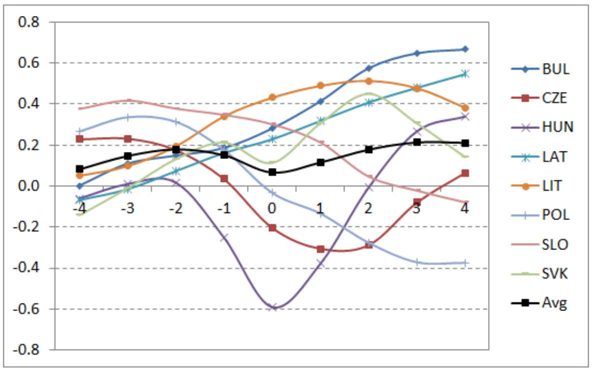
GDP$_t$ – REER$_{t+k}$



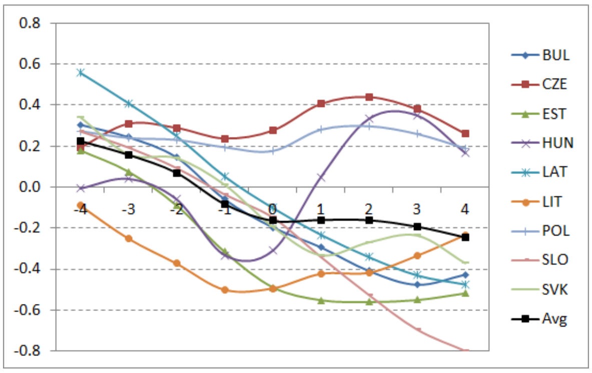
Long-term interest rate$_t$ – NEER$_{t+k}$



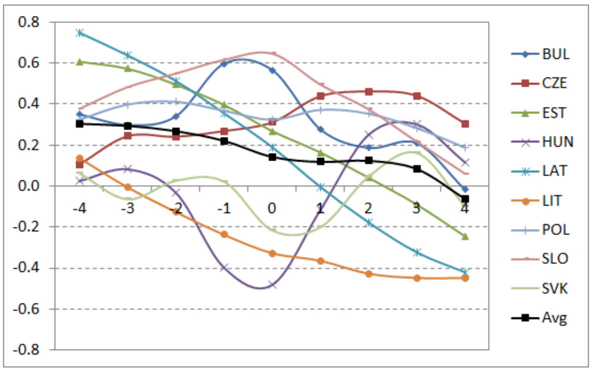
Long-term interest rate$_t$ – REER$_{t+k}$



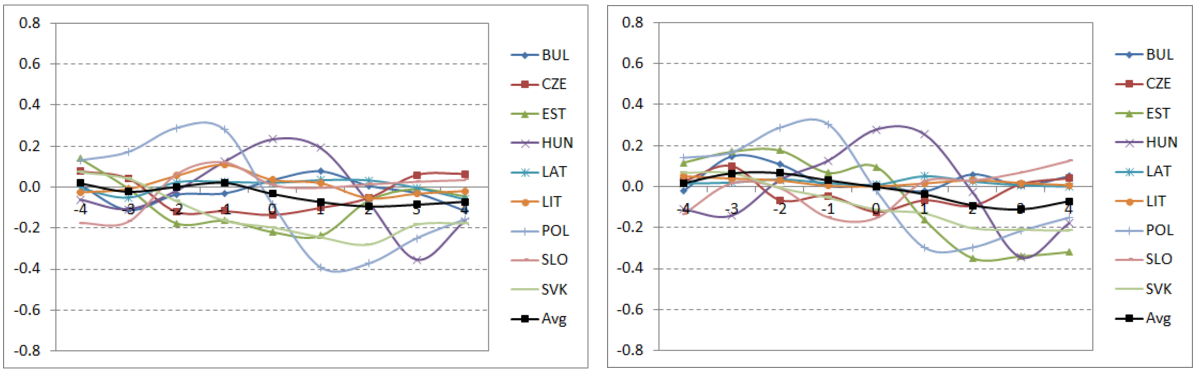
Money supply$_t$ – NEER$_{t+k}$



Money supply$_t$ – REER$_{t+k}$



Investment$_t$ – NEER$_{t+k}$ Investment$_t$ – REER$_{t+k}$



Note: Lags and leads refer to time shift of the exchange rate series. Estonia is not included in the cross correlation with long-term interest rates due to the unavailability of data.
Source: Authors' calculations

Regardless of the macroeconomic fundamental used in the cross correlations, it is apparent from the graphs that results differ substantially across the countries in both the value of correlation coefficients and the shape of the correlation curves. Therefore, the group of nine CEEC examined in this study can by no means be considered as homogeneous in terms of relationship between effective exchange rates and macroeconomic aggregates.

Before we proceed and discuss the relationships in detail, it is necessary to explain how the correlation curves should be interpreted. We can see that the pattern depicted resembles the letter S or reverse letter S. The S-curve shows that positive correlation coefficients can be found only between the current value of the macroeconomic fundamental and the future value of the exchange rate. In other words, the exchange rate is procyclical if it lags the fundamental but countercyclical if it leads the fundamental. By contrast, the reverse S-curve implies the opposite relationship pointing to procyclicality of the leading exchange rate and countercyclicality of the lagging exchange rate.

The use of two types of effective exchange rate indices in the correlation analysis caused considerably different results. While the relationships between NEER and GDP seem to be more consistent across the countries, the correlations between REER and GDP vary extensively but yield higher correlation coefficients. The average of the absolute values of correlation coefficients with REER is higher than the average with NEER in eight countries. The REER leads the GDP by 1 to 3 quarters. Correlation coefficients are generally positive and range from 0.14 for Hungary to 0.57 for Estonia indicating a procyclicality of the exchange rate as a leading variable. However, Lithuania and Slovenia show the highest coefficient if REER lags GDP by four quarters. The coefficients are approximately -0.28 and document the countercyclical behavior of REER as a lagging variable.

Correlation analysis between long-term interest rates and exchange rates resulted in mixed evidence but had one common finding. Although eight countries reported higher correlation coefficients with REER than NEER the differences are not significant and generally are smaller than 0.10. While the correlation peaks around the lag zero in some countries (Czechia, Hungary, Lithuania), others display an S-curve (Bulgaria, Latvia, Slovakia) whereas the remaining countries show a reverse-S-curve (Poland, Slovenia). The peak of correlation with NEER around the lag zero (e.g. 0.57 for Bulgaria and Lithuania or -0.51 for Hungary) indicates that NEER is frequently a coincident variable in relation to the long-term interest rate. On the other hand, correlations with REER typically culminate if REER lags the interest rate by two or three quarters (e.g. 0.65 for Bulgaria, 0.45 for Slovakia or -0.37 for Poland). Nevertheless, it is impossible to draw any universal conclusion on the form of cyclicality of REER because it varies from country to country.

The results of cross correlations between money supply and exchange rates are also inconsistent and hard to interpret in a universal way. However, the overall picture seems to be more standardized if we examine correlations with NEER. With the exception of Hungary, Lithuania, and to lesser degree Slovenia, the correlation rises with the increasing time shift of the exchange rate time series in both directions of the shift. The coefficients obtained in many countries can be considered as evidence of a very strong correlation (e.g. -0.75 for Latvian REER, -0.80 for Slovenian NEER or 0.61 for Estonian REER). The average correlation coefficients indicate a procyclicality of NEER at lags and countercyclicality at leads. In the case of REER, we can observe a procyclicality over almost the entire time shift range. Therefore, we can conclude that the money supply was revealed to be the macroeconomic variable with the strongest correlation with exchange rates.

The outcome of cross correlations between investment inflow and exchange rates are the most consistent among all macroeconomic fundamentals applied in the paper. However, all countries exhibit the lowest correlation coefficients in this combination. The coefficients rarely exceed the absolute value of 0.20 and the highest correlation coefficient was exhibited in countries with a floating exchange rate regime such as Hungary or Poland. The differences in coefficients between correlation with NEER and REER are usually negligible. The resulting average correlation curve is extraordinarily flat when compared to correlations with other macroeconomic fundamentals.

Due to the fact that the graphs in Figure 6 depict only a simple arithmetical average of correlation coefficients, we cannot use this measure to draw any conclusions on the lead/lag where the correlation is the most intensive. Therefore, Table 3 reports the highest average absolute values of national correlation coefficients and their respective lead/lag at which this mean value peaks. Clearly, coefficients in absolute values cannot be used for examination of procyclicality and countercyclicality of the exchange rates but only for the assessment of the correlation's strength.

Table 3: Highest average of absolute values of correlation coefficients with respective time shift

NEER							
GDP		Long-term interest rate		Money supply		Investment inflow	
average	shift	average	shift	average	shift	average	shift
0.1642	3	0.3001	0	0.4128	3	0.1444	1
REER							
GDP		Long-term interest rate		Money supply		Investment inflow	
average	shift	average	shift	average	shift	average	shift
0.2348	-3	0.2949	3	0.3704	0	0.1360	3

Source: Authors' calculations

The effective exchange rates appear to have the greatest average correlation with the money supply and, to a lesser extent, with long-term interest rates. The weakest average correlation was found for investment inflow. The strongest correlation between exchange rates and fundamentals is in most cases demonstrated at leads or lags of three quarters. This conclusion on the relative strength of correlation for the whole group of CEEC is supported by findings on the national level.

Table 4 presents the average of absolute values of correlation coefficients with all leads and lags. The strength of correlation is distinguished by the color of the background. While the white background suggests that the respective exchange rate and macroeconomic fundamental are uncorrelated, the grey background shows a weak correlation and the black background denotes a strong correlation. It should be mentioned that the thresholds delimiting no correlation, weak correlation and strong correlation are 0.13 and 0.26, respectively. It is apparent from Table 4 that the correlation between the money supply and effective exchange rates was determined to be strong in seven countries and weak in the two remaining CEEC. There was at least a weak correlation found between long-term interest rates and exchange rates in all countries; however, a strong correlation appeared in two countries. Conversely, just a few examples of weak correlation were revealed between investment inflow and exchange rates. There is no country used in this analysis which does not show at least a weak correlation in all combinations of fundamentals and exchange rates. However, we found evidence of certain correlation with three fundamentals in a majority of countries. Three countries (Bulgaria, Estonia, Lithuania) exhibit strong correlation with two macroeconomic fundamentals. In contrast, for two countries (Hungary, Slovakia) we found no evidence of strong correlation at all.

Table 4: Averages of absolute values of correlation coefficients in the analyzed countries

	GDP		Long-term interest rate		Money supply		Investment inflow	
	NEER	REER	NEER	REER	NEER	REER	NEER	REER
BUL	0.0760	0.1951	0.3187	0.3371	0.2841	0.3161	0.0504	0.0480
CZE	0.1060	0.1241	0.1418	0.1791	0.3104	0.3130	0.0857	0.0636
EST	0.2958	0.3629	n.a.	n.a.	0.3702	0.3201	0.1183	0.1999
HUN	0.0587	0.0713	0.2452	0.2138	0.1832	0.2002	0.1476	0.1662
LAT	0.1529	0.2304	0.2440	0.2555	0.3170	0.3747	0.0286	0.0198
LIT	0.1794	0.1521	0.2731	0.3307	0.3466	0.2803	0.0399	0.0218
POL	0.0782	0.1168	0.1946	0.2536	0.2382	0.3359	0.2363	0.2091
SLO	0.0678	0.1848	0.1920	0.2425	0.3452	0.4243	0.0684	0.0791
SVK	0.1254	0.1407	0.1775	0.2017	0.2286	0.1000	0.1587	0.1184

Source: Authors' calculations

Conclusions

According to theory, exchange rates are supposed to play an important role in the economy. On the one hand, exchange rates should be affected and determined by a variety of macroeconomic fundamentals. On the other hand, exchange rates are assumed to influence economic development in many ways on both a microeconomic and macroeconomic level. In this paper, we did not propose or test the validity of any exchange rate determination models. In addition, we did not estimate the impact of exchange rates and their volatility on the economy. Instead, we focused on the elementary precondition of those theories and models and provided direct empirical evidence of the existence and nature of the relationship between exchange rates and fundamentals. We also thoroughly examined the volatility and cyclicality of the effectve exchange rates in nine CEEC.

We delineated substantial differences in the results across the countries, which might have prevented us from drawing general conclusions and straightforward interepretations. However, there are several findings that are applicable to most of the countries incorporated in the research. The countries that apply a floating exchange rate arrangement usually experienced higher volatility and higher amplitude of the cycle phases. We determined that this conclusion is true regardless of the type of effective exchange rate used. In all of the countries examined, the trough-to-peak phase lasted longer than the peak-to-trough phase. Likewise, the average amplitude of the upward phase was typically higher than the amplitude of the downward phase of the cycle.

There is usually not a big difference in the strength of the relationship between the exchange rates and the macro fundamentals when we compare results based on NEER and REER. Therefore, the results do not confirm the theoretical assumption that in small open economies REER is more tightly related to macroeconomic fundamentals. Instead, it indicates more about the international competitiveness of an economy. While the money supply seems to be the most highly correlated fundamental, relatively weak relationships were revealed between exchange rates and foreign investment inflow. However, the results obtained allow us to conclude that policy analyses related to business cycles should not overemphasize the effects of exchange rates on the economy and crucial fundamentals. Additionally, the applicability of standard exchange rate determination models can be limited in CEEC.

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