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Exchange Rate and Oil Price Interactions in Transition Economies: Czech Republic, Hungary and Poland

Summary: This study investigates causal dynamics between crude oil prices and exchange rates in Czech Republic, Poland and Hungary by employing monthly data from the beginning of flexible exchange regime in each country to December 2011. The study benefits from the recent advance in the time series econometric analysis and carries out linear causality, non-linear causality, volatility spillover and frequency domain causality tests. The frequency domain causality analysis results imply that oil price fluctuations affect real exchange rates in the long run in Poland and Czech Republic. On the other hand, frequency domain causality test results indicate that oil price fluctuations do not affect exchange rate in any period in Hungary despite its economy's high imported energy dependency.

Key words: Oil prices-exchange rates relationship, Transition countries, Frequency domain.

JEL: C32, F31, F41, Q43.

The term of transition economies includes the countries located in Central and Eastern Europe. Most of them are former member of Soviet Union while others belong to former Eastern European bloc. The definition of transition countries can be widened by including the countries out of Europe. The common point of all the countries is that they emerge from a socialist type command economy towards a market based economy. The key objectives of transition are to raise economic efficiency and promote growth, International Money Fund (IMF 2000). In this regard, macroeconomic stabilization, price and market liberalization, restructuring and privatizing state enterprises and redefining the role of the state are the main steps of the transition process.

During the last two decades, these countries went through significant economic and political transformations by launching wide-ranging economic and financial reform programs. On the other hand, they exhibit rather similar economic and political conditions at the beginning of transition process, they demonstrate different performances in economic growth during this period. In this regard, Erdener Kaynak and Zenfira Nasirova (2005) put the transition countries into three groups. First group consists of advanced transition countries: Czech Republic, Estonia, Hungary, Lithuania, Poland, Slovakia and Slovenia. The first group countries have relatively

high gross domestic product (GDP) *per capita*. The second group consists of developing transition countries and their GDP *per capita* are less than 10.000 U.S. dollar. Belarus, Bulgaria, Kazakhstan, Latvia, Romania, Russian Federation, Turkmenistan and Ukraine are in this group. The last group of countries has less than 5.000 U.S. dollar and are named less developed transition countries. These countries are Georgia, Kyrgyzstan, Tajikistan, Uzbekistan, Moldova and Azerbaijan.

Although Louis-Maire Philippot (2010) concludes that the economic growth differences between transition countries depend on inequalities in natural resource endowments and analyses show that the development level of country or the level of transition mainly depends on meeting of requirements of transition. While the first group of countries has already met the requirements of transition process such as large and small-scale privatization, governance, enterprise restructuring and banking reform just before the end of 2000s, IMF (2000) reports that other transition countries have a number of processes to achieve.

Another important step in transition process is about the policy of trade and foreign exchange. The choice of a sustainable exchange rate regime in emerging and transition economies is essential and complex question in the current context of globalization and international financial fluctuations emerge (Celine Gimet 2010). While the advanced transition countries implemented fixed or managed exchange rate regime during the first period of transition process, they have started to implement floating or at least more flexible exchange rate regime in the second stage of the transition period. By being a member of European Union, most of the advanced transition countries are included into European Monetary Union in the context of financial integration in Europe. Slovenia joined the Monetary Union in 2007 and Slovakia entered into the Union in 2009. Estonian Euro entered circulation on first of January 2011. Lithuania announced to join European Monetary Union by the beginning of 2013. Lastly, Latvia joined to the system by first of January 2014. However, Hungary, Poland and Czech Republic are not still a member of European Monetary Union, despite their membership to European Union. Hungary has declared the membership by 2012, but they have not revised the target date for participation to Monetary Union yet. But there is no declaration about membership of Czech Republic. On the other hand, Poland plans to participate in the Union after 2015, but the exact date for participation is not clear.

At the beginning of 1990s, Hungary adopted an adjustable peg system and the official exchange rate was linked to a basket of 50 percent U.S. dollar and 50 percent German Mark until May 1994 in order to decrease inflation rate. In other words, Hungary followed an active exchange rate regime based on a currency peg with a narrow band of permitted fluctuations in the early 1990s (Selahattin Dibooglu and Ali M. Kutan 2000). After the 1994 Mexican crisis, the Hungarian government realized that they could not control the inflation and current account balance at the same time, since the 1994 Mexican crisis increased the risk premium for emerging markets which worsened the ability to borrow in international markets. Therefore, in 1995, the Hungarian government and the central bank decided to adopt a crawling band regime which was widened in October 2001. In 2008, the crawling band regime was fully eliminated (Balázs Vonnák 2010). In this regard, we may interpret the exchange rate regime as more flexible since October 2001.

Poland started to practice reforms in January 1990 with the adoption of fixed exchange rate in which the Polish currency was tied to the U.S. dollar. As a result of devaluation in May 1991, the exchange rate regime which was linked only to U.S. dollar was changed to a forward looking crawling basket peg. In May 1995, Poland took a new step toward higher exchange rate flexibility and adopted a crawling corridor or target zone with fluctuation margins of +/-7%. This more flexible exchange rate regime was utilized from May 1995 to April 2000. In April 2000, Poland finally adopted a flexible exchange rate regime (Kosta Josifidis, Jean-Pierre Allegret, and Emilija Beker Pucar 2009).

Czech Republic, with Slovakia, was originally a constituent of Czechoslovakia. In January 1993, Czechoslovakia was divided into the Czech Republic and Slovakia. The transition reforms of Czech Republic started in January 1990 by choosing a conventional fixed exchange rate regime with narrow fluctuation margins. This fixed exchange rate regime with a basket peg including the currencies of key trading partners; Germany, the United States, Austria, Switzerland and the United Kingdom, was utilized until February 1996. After this date, the Czech Republic adopted an intermediate exchange rate regime which had more extensive fluctuation margins and abandoned the exchange rate targeting. However, in May 1997, the Czech currency significantly depreciated due to speculative attacks, thus, Czech Republic moved from the intermediate exchange rate regime to managed floating exchange rate regime (Josifidis, Allegret, and Beker Pucar 2009). In this context, we interpret the regime change as a transition to a more flexible exchange rate regime, as accepted by Yutaka Kurihara (2012).

In Figure 1, we demonstrate the movements of real exchange rate by the beginning of flexible exchange rate regime for each economy. Exchange rate fluctuations can be seen in the figure for all countries.

Source: IMF, International Financial Statistics Database[1].
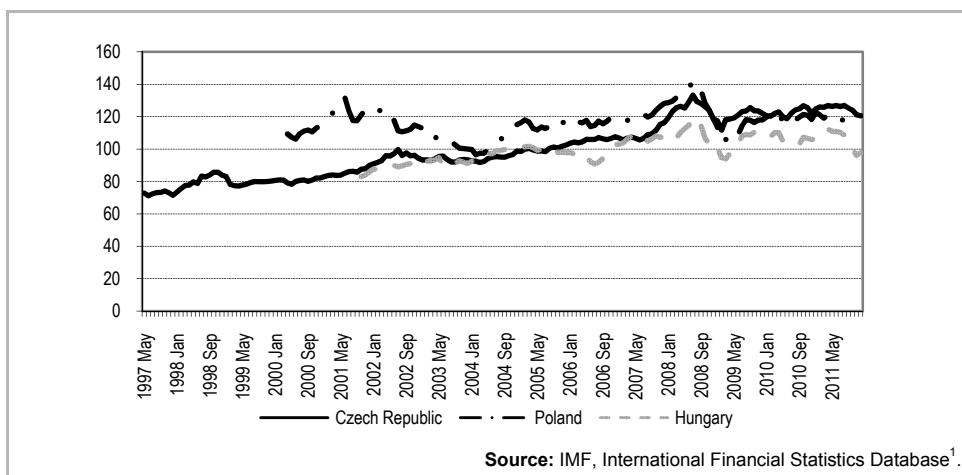
Figure 1 Real Exchange Rate Series in Czech Republic, Hungary and Poland

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[1] **International Monetary Fund (IMF).** 2012. International Financial Statistics Database. http://elibrary-data.imf.org/ViewData.aspx?qb=8df59be04035e5a22753acae323b66a1 (accessed February 10, 2012).

Other important topics in transition countries are the energy consumption and the energy dependency of these countries during the transition period. As indicated by Mehmet Mucuk and Ibrahim H. Sugozu (2011), there is a positive linkage between energy consumption and economic growth in sectoral basis as well as in whole economy. This is also valid for transition countries. According to Eurostat database, primary energy consumption of Czech Republic was 42.000 TOE (thousand tones of oil equivalent) in 2010, while Poland consumed more than 96.000 TOE in the same year. Hungary consumed 24.000 TOE in 2010 and it was lower than consumption of Czech Republic and Poland. Despite its higher energy demand than the other two countries, Czech Republic is one of the lowest energy import dependencies in the European Union because of domestic solid fuel and nuclear energy production according to report of European Commission (EC 2007). Despite its low import energy dependency, Czech Republic imported 8.800 TOE oil from Russian Federation (Russia, hereafter) and the amount of oil import covers 55% of total energy import in 2004. The share of imported oil in total energy consumption is nearly 20%.

Poland is another country which has one of the lowest energy import dependency in European Union. According to report of EC (2007), the hard coal plays a very significant role in Polish energy mix. Poland consumed 22.000 TOE oil in 2004 and although its low energy dependency like Czech Republic, Poland imported 21.000 TOE oil from abroad, mainly from Russia. This covers 72% of total energy import. By the way, the import energy dependency of Poland has been increasing in previous years. According to Table 1, while Czech Republic's import energy dependency has been constant during last four years, it has been increasing as seen in the case of Poland.

Lastly, Hungary is more energy import dependent country than the other two countries. Russia is the main source of imported gas and oil. While the total oil demand was 6.300 TOE in 2004, Hungary imported 4.900 TOE oil from Russia. Energy dependency of Hungary has been decreasing in recent years. It was 62% in 2007, while it was 57% in 2010 as seen in the table. But it is still more than 50% and this is slightly higher than European Union average. Meanwhile gas is the main energy source which imported from abroad. While the share of gas is 55% in total energy imports, it is only 31% for oil.

Table 1   Energy Imports (% of Energy Use)

Country	2007	2008	2009	2010
Czech Republic	26	26	26	26
Hungary	62	60	56	57
Poland	25	27	28	33

Source: World Bank (2012)[2].

In addition to transition of these countries from fixed exchange rate regime to flexible regime, import dependencies of the countries, the amount of imported oil and remarkable share of oil in energy consumption bring to question that: "Are oil price

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[2] **World Bank (WB).** 2012. Energy and Mining Database.
http://data.worldbank.org/indicator/EG.USE.PCAP.KG.OE (accessed February 10, 2012).

fluctuations related to exchange rate fluctuations in these countries?" Although there are a number of macroeconomic variables affecting exchange rate and oil prices, determining the possible relationship between oil prices and exchange rates deepens our insights for better understanding the dynamics of exchange rate. The determination of interaction between variables gives useful information for policymakers in designing exchange rate policy. A fluctuating exchange rate impairs on economic growth (Johanna Rickne 2009). Rickne (2009) attributes her thought to Luis Serven and Andres Solimano (1993) and Michele Bagella, Leonardo Bechetti, and Iftekhar Hasan (2006) findings. According to Serven and Solimano (1993), fluctuations stemming from volatile oil prices are damaging to the non-oil sector and to capital formation. Bagella, Bechetti, and Hasan (2006) also imply that fluctuations lead to decrease in *per capita* income. The determination of possible causal relationship running from oil price to exchange rate would provide important information for policymakers in order to apply right policies for reducing volatility in national currency because of shock in oil price. On the other hand, the information about possible interaction between oil prices and exchange rate plays crucial role in making long term energy policies. By determining the causation linkage, policymakers might tend to alternative energy sources in order to reduce oil dependency and/or oil demand.

In this regard, we examine the causation linkage between exchange rate and oil price interactions in this study. We analyze only three transition countries; namely Czech Republic, Hungary and Poland, those have changed their exchange rate regime from a fixed to a more flexible one during the transition process (Jérôme Creel and Sandrine Levasseur 2004). We employ monthly data from the beginning of flexible exchange rate regime in Hungary, Czech Republic and Poland to December 2011. Although previous empirical researches have examined this relationship using a range of linear econometric techniques, there are not so many studies those examine the oil price-exchange rate interaction with non-linear techniques. Indeed, most empirical studies dealing with causality focused on linear relationships. But, given the growing evidence on the non-linear dynamic of economic and financial time series, there has been an increasing interest in non-linear causality.

This paper also attempts to compare time domain causality analysis methods and frequency domain causality analysis method which generates test statistics at different frequencies across spectra. By doing so, we will be able to examine the existence of causality between variables in different time horizons, namely short, medium and long run. Distinguishing short and long run causal linkages between oil prices and exchange rates provides important policy implications because the supply and demand elasticity of oil prices tends to differentiate from short- to long-run (Virginie Coudert, Valerie Mignon, and Alexis Penot 2007). In this regard, we employ the bootstrap process-based Toda-Yamamoto linear causality test introduced by R. Scott Hacker and Abdulnasser Hatemi-J (2006), non-linear causality test introduced by Cees G. H. Diks and Valentyn Panchenko (2006), causality in variance (i.e., volatility spillover) test introduced by Christian M. Hafner and Helmut Herwatz (2006), and finally frequency domain causality test approach introduced by Jörg Breitung and Bertrand Candelon (2006).

The rest of the paper is organized as follows. The next section is devoted to summarize theoretical background investigating the causation linkage between oil

prices and exchange rates. Section 2 summarizes the existing literature investigating the relationship between variables. In the Sections 3 and 4, econometric methodology and the data are described. In the Section 5, empirical results are presented. We summarize and conclude empirical findings in the last section.

1. Theoretical Background

In flexible exchange rate regimes, a number of factors induce the exchange rate fluctuations. The determination of factors which induce exchange rate volatility is important because of its effect on economy. In this regard, driving forces of exchange rate fluctuations highly debated for the recent years. As indicated by Pavle Petrović and Mirjana Gligorić (2010) exchange rate fluctuations are effective on economic factors such as trade balance. The monetary factors as well as real macro economic variables are examined by economists in order to find the effects of these factors in exchange rate volatility. While some authors attribute roles to monetary factors, Hamid Faruqee (1995), Nelson C. Mark and Doo-Yull Choi (1997) suggest that real economic variables play crucial role in identification of exchange rate fluctuations.

A group of economists suggest that oil price shock is a source of exchange rate fluctuations. Indeed, James D. Hamilton (2003) and Lutz Kilian (2006) emphasize the effects of oil price shocks on the macroeconomic variables such as economic growth, inflation, etc. According to them, oil price can affect the economy in a linear or non-linear way. In this regard, the possible linear and non-linear effects of oil price shocks on exchange rates have investigated in the literature by the economists. Initially, Stephen S. Golub (1983) explains the transmission mechanism of the possible effect of oil price shocks on exchange rate *via* savings and wealth transfer channels. According to him, an oil price shock would induce a wealth transfer from oil importing country to oil exporting country and it would reduce the value of national currency. Another explanation of this impact utilizes the terms of trade and net foreign assets. An increase in oil price could deteriorate the terms of trade and then leads to an increase in the national currency of oil importing countries.

On the other hand, Coudert, Mignon, and Penot (2007) investigate the causation linkage running from exchange rate to oil price. According to them, the impact of the U.S. dollar on the oil prices can be explained as follows: although U.S. dollar is the major invoicing and settlement currency in international oil markets, oil demand depends on the domestic price for consumer countries which changes with the U.S. dollar. Therefore, a decrease in U.S. dollar leads to a decrease in the oil price in oil importing countries, which in turn leads to an increase in their oil demand. As a result of the increase in demand, the price of oil rises. On the other hand, depreciation in U.S. dollar causes a reduction in the oil income of oil exporting countries. A decrease in the real income of oil leads to a decrease in drilling, namely a reduction in supply, which increases oil prices in the long run.

2. Literature Review

There is a vast literature on the relationship between exchange rates and oil prices. The existing empirical literature explored mostly the influence of oil prices on the

exchange rate. The influence of oil prices on the exchange rate movements is studied early by Paul R. Krugman (1980) and Golub (1983). They conclude that an oil-exporting (oil-importing) country may experience exchange rate appreciation (depreciation) when oil prices rise and depreciation (appreciation) when oil prices fall. Robert A. Amano and Simon van Norden (1998) report that oil prices explain real exchange rate shocks. Mariam Camarero and Cecilio Tamarit (2002) examine the effect of oil price in the long-term real exchange rate for the Spanish peseta. They find that the oil price is one of the main determinants of the Spanish exchange rate. Ying Huang and Feng Guo (2007) investigate the relationship for China and find that real oil price shocks led to a minor appreciation in China's real exchange rate. Shiu-Shen Chen and Hung-Chyn Chen (2007) find that real oil price fluctuation has a significant effect on the real exchange rate movements in the G7 nations. Giulio Cifarelli and Giovanna Paladino (2010) and Radhamés A. Lizardo and André V. Mollick (2010) find a significant negative relationship from oil prices to exchange rates. Similarly, Kausik Chaudhuri and Betty C. Daniel (1998), Eisa A. Aleisa and Dibooglu (2002), Nikola Spatafora and Emil Stavrev (2003), Q. Farooq Akram (2004), Ramzi Issa, Robert Lafrance, and John Murray (2006), Maurizio M. Habib and Margarita Manolova Kalamova (2007), Hilde C. Bjornland and Havard Hungnes (2008), Mohammad R. Jahan-Parvar and Hassan Mohammadi (2008), Paresh K. Narayan, Seema Narayan, and Arti Prasad (2008), Iikka Korhonen and Tuuli Juurikkala (2009), Fakhri Hasanov (2010), Leili Nikbakht (2010) and Diego Mendez-Carbajo (2011) conclude that oil price shocks cause exchange rate fluctuations.

On the other hand, the potential effect of exchange rates on oil price movements is first highlighted by S. Brock Bloomberg and Ethan S. Harris (1995). According to Bloomberg and Harris (1995), oil is a homogeneous and internationally traded commodity priced in U.S. dollar. As result of this fact, depreciation in U.S. dollar against a currency of a foreigner country reduces the oil price of this country relative to the price of its commodities in foreign currencies, thereby increasing their purchasing power and oil demand and, in turn, increasing the oil price in U.S. dollar. Likewise, Perry Sadorsky (2000) investigates the interaction between oil prices and exchange rates and finds Granger causality running from exchange rates to oil futures prices. Jean-Pierre Indjehagopian, Frederic Lantz, and Vienne Simon (2000) report the interactions between German, French, and Rotterdam heating oil spot prices and the DEM/USD and FRF/USD exchange rates. They find that a change in the exchange rates has an immediate effect on the oil prices. Yue-Jun Zhang et al. (2008) conclude that U.S. dollar has an impact on oil prices over the long-term but no significant impact in the short-term. Noureddine Krichene (2005), Akram (2009), Emre Ozsoz and Mustapha Akinkunmi (2011) and Suleiman Hassan and Mohammad Zahid (2011) also find evidence supporting causality running from exchange rate to oil price.

Third group of studies find bi-directional causality between oil prices and exchange rates. These studies, despite their mixed implications, tend to suggest that oil prices and exchange rates probably both contain information that can affect each other. Some of these studies are: Al-Mulali Usama and Che Sab Normee (2009), Yu-Chin Chen, Kenneth S. Rogoff, and Barbara Rossi (2010), Jan J. Groen and Paolo A.

Pesenti (2010), Alexi Y. Huang and Yi H. Tseng (2010), Mohammadi and Jahan-Parvar (2010), and Akira Yanagisawa (2010).

3. Methodology

3.1 Linear Granger Causality Test

In a standard Granger causality analysis, zero restrictions based on the Wald principle are imposed on the lagged coefficients obtained from the estimation of Vector Autoregressive (VAR) model. However, the Wald statistic may lead to nonstandard limiting distributions depending upon the cointegration properties of the VAR system that these nonstandard asymptotic properties stem from the singularity of the asymptotic distributions of the estimators (Helmut Lütkepohl 2004). The Hiro Y. Toda and Taku Yamamoto (1995) (TY, hereafter) procedure overcomes this singularity problem by augmenting VAR model with the maximum integration degree of the variables. In addition to this advantage, the TY approach does not require testing for cointegration relationships and estimating the vector error correction model and is robust to the unit root and cointegration properties of the series.

3.2 Non-Linear Granger Causality Test

The linear Granger causality test does not account for non-linear causal relationships among the variables. In order to test for non-linear Granger causality, various nonparametric methods are developed. In an early study, Ehung G. Baek and William Brock (1992) propose a nonparametric statistical method for detecting non-linear Granger causality by using correlation integral between time series. In the Baek and Brock's test, the time series are assumed to be mutually and individually independent and identically distributed. By relaxing this strict assumption, Craig Hiemstra and Jonathan D. Jones (1994) develop a modified test statistic for the non-linear causality which allows each series to display short-term temporal dependence. However, Diks and Panchenko (2005) show that the test advocated by Hiemstra and Jones (1994) may over reject the null hypothesis of non-causality in the case of increasing sample size since it ignores the possible variations in conditional distributions. In a recent study, Diks and Panchenko (2006) (hereafter DP) develop a new nonparametric test for Granger causality that overcomes the over-rejection problem in the Hiemstra and Jones's test.

3.3 Causality-in-Variance (Volatility Spillover) Test

Even though linear and non-linear causality methods are capable of capturing of predictive power from one variable to another variable, they are not able to detect volatility spillover between two variables since volatility corresponds to fluctuations in variance of data. Thereby, in addition to analyzing causality, it is useful to conduct causality-in-variance test to better understand relationship between exchange rates and oil prices. In order to determine the volatility spillover, this study adopts the causality in variance test recently developed by Hafner and Herwartz (2006).

3.4 Frequency Domain Causality Test

While conventional time domain causality tests produce a single test statistic for the interaction between variables in concern, frequency domain methodology generates tests statistics at different frequencies across spectra. This is contrary to the implicit assumption of the conventional causality analysis that a single test statistic summarizes the relation between variables. Frequency domain approach to causality thereby permits to investigate causality dynamics at different frequencies rather than relying on a single statistics as is the case with the conventional time domain analysis (Cetin Ciner 2011). Hence, it seems to be very meaningful to carry out frequency domain causality to better understand temporary and permanent linkages between oil prices and exchange rates in the countries investigated.

4. Data

In this study, we use the real exchange rates (RER) and the relative oil price (ROP) of each country in order to find the relationship between the oil prices and exchange rates. In the literature, the related papers employ different type of exchange rate definition such as nominal and real exchange rate calculated by using different price indices. In this study, we employ real exchange rate due to its explanatory power and it is defined as the foreign currency price of the U.S. dollar, concluding that the dollar appreciates as the nominal value of exchange rate raises. Real exchange rates (RER) are constructed using consumer price indices. In this regard, we use bilateral exchange rate of the local currency into U.S. dollar for each of three countries. Also we use U.S. price index as foreign price index.

In order to obtain the relative oil price for each country, the world price of oil quoted in U.S. dollar is first converted into domestic price by using the U.S. dollar exchange rate of the relevant country and then it is deflated by the domestic consumer price index.

The data are obtained from International Financial Statistics database. We employ monthly data from May 1997 to December 2011 for Czech Republic, from April 2000 to December 2011 for Poland and from October 2001 to December 2011 for Hungary. Since the date of transition to floating exchange rate regime[3] differentiates among countries, the data span also differentiates. The exchange rate and oil price series are transformed into logarithmic form. The descriptive statistics are reported in Table 2.

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[3] Hungary adopted a crawling band regime with a bandwidth of ±15 percent, which is sufficiently widen. Therefore, it is taken into the analysis along with the countries with floating exchange rate regime. Also we accepted the beginning of flexible exchange rate regime in Czech Republic according to implications of Kurihara (2012).

Table 2   Descriptive Statistics

Country	Time span	Variable	Mean	Std. dev.	Coef. of var.	Skewness	Kurtosis
Czech Republic	May 1997 - December 2011	RER	4.74	0.091	0.019	-0.321	1.604
		ROP	2.573	0.189	0.073	-0.935	3.715
Poland	April 2000 - December 2011	RER	4.751	0.079	0.016	-0.233	3.296
		ROP	0.481	0.296	0.615	-0.194	2.161
Hungary	October 2001 - December 2011	RER	4.624	0.058	0.012	-0.227	2.651
		ROP	4.792	0.205	0.042	-0.488	2.870

Notes: Coefficient of variation is the ratio of standard deviation to mean. Descriptive statistics are for log series. ROP: relative oil prices, RER: real exchange rates.

Source: Authors' estimations.

5. Empirical Findings

In order to determine the integration degree of the variables, the unit root tests developed by David A. Dickey and Wayne A. Fuller (1979) (henceforth ADF), Peter C. B. Phillips and Pierre Perron (1988) (henceforth PP) and Graham Elliot, Thomas J. Rothenberg, and James H. Stock (1996) (henceforth DF-GLS) are employed. The results of the unit root tests are shown in Table 3. According to the results of the unit root tests, except for a few cases, the null hypothesis of unit root is not rejected for the levels of real exchange rate and relative oil price in all countries. Therefore, it could be said that the variables are integrated of order one. As a result, the maximum integration order (d) of the variables is taken one in the TY procedure and the series are transformed into first difference before the analysis.

According to linear TY Granger causality test results, shown in Table 4, there is no causation linkage from real exchange rates to relative oil prices. However, the results show that there is a uni-directional causality from relative oil prices to real exchange rates in Czech Republic and Hungary. Overall, according to the linear TY Granger causality test results relative oil price shocks affect real exchange rates in the Czech and Hungarian economies.

Since the linear causality methods may overlook non-linear relations, we examine the non-linear causal linkages between relative oil prices and exchange rates. The non-linear Granger causality test is carried out in two steps as in the study of Stelios D. Bekiros and Diks (2008). In the first step, the DP test is applied to the stationary series in order to determine the non-linear relationships. In the second step, to see whether there is a strict non-linear causality in nature, the DP test is reapplied to the filtered VAR residuals. After removing linear causality with a VAR model, any causal linkage from one residual series of the VAR model to another can be considered as non-linear predictive power (Hiemstra and Jones 1994). In the DP test, the value of the bandwidth plays an important role in making a decision on existence of non-linear causality. Since the bandwidth value smaller (larger) than one generally results in larger (smaller) p-value (Bekiros and Diks 2008), the bandwidth value is set to one and the results are discussed for one lag ($lx=ly=1$). According to non-

Table 3   Results for Unit Root Test

Levels	Country		ADF	DF-GLS	PP
Intercept	**Czech Republic**	RER	-1.294 (0)	1.011 (0)	-1.301 (5)
		ROP	-1.907 (1)	-1.4587 (1)	-1.763 (3)
	Poland	RER	-2.596 (1)*	-2.289 (1)**	-2.107 (5)
		ROP	-1.470 (1)	-0.830 (1)	-1.472 (4)
	Hungary	RER	-2.780 (1)*	-0.983 (1)	-2.660 (3)*
		ROP	-1.257 (0)	-0.278 (0)	-1.480 (3)
Intercept and trend	**Czech Republic**	RER	-2.220 (0)	-2.298 (0)	-2.925 (6)
		ROP	-2.963 (1)	-2.837 (1)	-2.833 (3)
	Poland	RER	-2.350 (1)	-2.456 (1)	-1.860 (5)
		ROP	-3.576 (1)**	-3.486 (1)**	-3.062 (2)
	Hungary	RER	-3.269 (1)*	-2.591 (1)	-2.771 (4)
		ROP	-2.902 (1)	-2.926 (1)	-2.553 (1)
First-differences					
Intercept	**Czech Republic**	RER	12.050 (0)***	-2.318 (3)**	-12.183 (5)***
		ROP	-10.475 (0)***	-9.067 (0)***	-10.508 (3)***
	Poland	RER	-7.642 (0)***	-6.643 (0)***	-7.578 (3)***
		ROP	-9.909 (0)***	-1.213 (4)	-9.894 (12)***
	Hungary	RER	-7.970 (0)***	-7.308 (0)***	-7.943 (2)***
		ROP	-9.239 (0)***	-3.896 (1)***	-9.146 (7)***
Intercept and trend	**Czech Republic**	RER	12.082 (0)***	-5.330 (1)***	-12.200 (4)***
		ROP	-10.449 (0)***	-10.111 (0)***	-10.482 (3)***
	Poland	RER	-7.730 (0)***	-7.226 (0)***	-7.658 (3)***
		ROP	-9.913 (0)***	-6.228 (0)***	-9.954 (12)***
	Hungary	RER	-8.035 (0)***	-8.009 (0)***	-8.011 (2)***
		ROP	-9.197 (0)***	-7.860 (0)***	-9.100 (7)***

Notes: For the ADF test: * shows the results of Dickey Fuller test in the case of zero lag length and lag length choosen due to SIC criteria. ** for the ADF test, the James G. MacKinnon (1996) critical values for a model with constant are -.3.485, -2.885, -2.579 at the 1%, 5% and 10% levels. The critical values for with constant and trend -4.035, -3.447 and -3.148 at the 1%, 5% and 10% levels, respectively.

For the DF-GLS test: * the asymptotic critical values for without trend -2.591, -1.944 at the 1% and 5% levels. ** the asymtotic critical values for with trend -3.602, -3.177 at the 1% and 5% levels. The figures in parenthesis denote the number of lags in the tests that ensure white noise residuals. They were estimated through the Schwarz criterion.

For the PP test: * values in the paranthesis show bandwiths obtained according to Newey-West using Bartlett Kernel criteria. ** for the PP test MacKinnon (1996) critical values for with constant -3.483, -2.884, -2.579 at the 1%, 5% and 10% levels. The critical values for with constant and trend -4.033, -3.446 and -3.148 at the 1%, 5% and 10% levels, respectively.

Source: Authors' estimations.

linear Granger causality test, there is no causal relationship between the variables in any countries. As seen in Table 5, for both directions and for all countries, the null hypothesis of no non-linear Granger causality relationship is not rejected. In other words, neither oil price shocks nor exchange rate fluctuations do affect each other.

Table 4 Linear TY Granger Causality Test Results

		RER to ROP		
		Bootstrap critical values		
	Statistic	1%	5%	10%
Czech Republic	3.763 (0.288)	12.075	8.167	6.502
Poland	4.521 (0.210)	11.551	7.918	6.332
Hungary	3.150 (0.369)	11.849	8.050	6.420
		ROP to RER		
		Bootstrap critical values		
	Statistic	1%	5%	10%
Czech Republic	10.432 (0.010)**	12.061	8.029	6.340
Poland	4.488 (0.213)	12.005	8.136	6.402
Hungary	7.533 (0.056)*	12.268	8.291	6.532

Notes: ***, **, and * denote statistical significance at the 1%, 5%, and 10% level of significance, respectively. The value in the paranthesis shows the *p*-value. The SBC was used to determine the optimal lag lengths for VAR(*p+d*) models. Bootstrap critical values are obtained from 10000 replications.

Source: Authors' estimations.

Table 5 Non-Linear Granger Causality Test Results

	RER to ROP			
	Raw data[a]		Residuals[b]	
	Statistic	*p*-value	Statistic	*p*-value
Czech Republic	-0.952	0.829	-1.901	0.971
Poland	-0.050	0.520	-0.289	0.613
Hungary	1.141	0.126	1.443	0.119
	ROP to RER			
	Raw data[a]		Residuals[b]	
	Statistic	*p*-value	Statistic	*p*-value
Czech Republic	0.445	0.328	-0.064	0.525
Poland	0.143	0.443	-0.837	0.798
Hungary	0.831	0.202	0.731	0.232

Notes: ** denote statistical significance at the 5% level. [a]: the series in first differences; [b]: the residuals of the VAR(*p+d*) models. The resulst are based on one lag; *p* is the number of lags and *d* is the maximum stationary level of variables.

Source: Authors' estimations.

Although linear and non-linear causality methods are capable of capturing of predictive power from one variable to another variable, they are not able to detect volatility spillover between two variables. Therefore, it is useful to conduct causality-in-variance test to better understand price transmission mechanism between exchange rates and oil prices. The Hafner and Herwartz (2006) causality-in-variance test is carried out and the results are shown in Table 6. The causality-in-variance test requires estimating GARCH(1,1) models, but in order to save space, the results from the GARCH(1,1) estimations are not reported here. The causality-in-variance test results, analogous with the non-linear Granger causality test results, suggest that there is no causality between the relative oil price and real exchange rate in any countries.

Table 6 Causality-in-Variance Analysis Results

	RER to ROP		ROP to RER	
	Statistic	*p*-value	Statistic	*p*-value
Czech Republic	4.043	0.132	0.888	0.641
Poland	1.152	0.561	2.265	0.322
Hungary	1.850	0.396	2.459	0.292

Notes: ***, **, and * denote statistical significance at the 1%, 5% and 10% level of significance, respectively.

Source: Authors' estimations.

The last causality test to detect a causal relationship between the variables is the frequency domain causality test developed by Breitung and Candelon (2006). It is a version of John Geweke's (1982) causality tests in frequency domain. Breitung and Candelon's (2006) approach provides an elegant interpretation of the frequency-domain Granger-causality as a decomposition of the total spectral interdependence between two series into a sum of "instantaneous", "feedforward" and "feedback" causality terms. The originality of this measure of Granger-causality is that it can be applied across all periodicities (e.g., in the short run, in the medium term and in the long run) and hence, one can get to know exactly for which periodicity one variable can Granger-cause the other. We calculate the test statistics at a high frequency of $\omega_i = 2.5$ and $\omega_i = 2.0$ to examine short-term causality, $\omega_i = 1.00$ and $\omega_i = 1.50$ to examine medium-term causality and finally $\omega_i = 0.01$ and $\omega_i = 0.05$ to investigate long-term causality. The results of the causality tests in the frequency domain are presented in Table 7. As seen in Table 7, while there is a bi-directional causality between variables in the long run in the case of Czech Republic, there is uni-directional causality running from real oil price to real exchange rate in the long run in Poland. These results imply that an oil price shock induces exchange rate fluctuations just in the long run. On the other hand, frequency domain causality analysis results indicate that there is no causation linkage between variables on any time period in the case of Hungary.

Table 7 Frequency Domain Causality Test Results

	RER to ROP					
	Long-term		Medium-term		Short-term	
ω_i	0.01	0.05	1.00	1.50	2.0	2.50
Czech Republic	8.893*	2.911	2.212	4.008	0.019	2.141
Poland	4.729	0.861	3.419	5.383	1.854	0.300
Hungary	0.111	2.103	1.564	2.255	4.582	1.169

	ROP to RER					
	Long-term		Medium-term		Short-term	
ω_i	0.01	0.05	1.00	1.50	2.00	2.50
Czech Republic	1.520	8.656*	3.249	3.433	3.896	0.538
Poland	8.151*	5.682	3.093	0.593	4.180	4.015
Hungary	3.635	4.088	2.168	0.127	2.802	1.009

Notes: The lag lengths for the VAR models are determined by SIC. * denotes the existence of causality.

Source: Authors' estimations.

The results imply that non-linear causality test and causality-in-variance test results do not find any causation linkage between variables. On the other hand, linear causality analysis finds evidence about the existence of causality running from rela-

tive oil price to real exchange rate in Czech Republic. Although there is a uni-directional causality in Hungary, significance level is low.

Frequency domain causality analysis results slightly differentiates from time domain analyses results. According to results, there is uni-directional causality from relative oil prices to real exchange rates in Poland and bi-directional causality in Czech Republic. All the interactions occur in the long run.

6. Conclusions

This paper examines the interactions and feedbacks between the real exchange rates and the real oil prices in Czech Republic, Poland and Hungary for the time period that begin from May 1997 for Czech Republic, April 2000 for Poland and October 2001 for Hungary and end with December 2011. To this end, we make use of the bootstrap process based Toda-Yamamoto linear causality test, the non-linear causality analysis, causality-in-variance test and frequency domain causality test.

First of all, time domain and frequency domain test results indicate slightly different results. While Toda-Yamamoto Granger causality test suggests an evidence for the causality in Czech Republic running from relative oil price to real exchange rate, the non-linear Granger causality and the causality-in-variance test results show that there is no causality between the relative oil price and real exchange rate in any countries.

On the other hand, the frequency domain causality test results show the existence of bi-directional causality in Czech Republic in the long run. Additionally, frequency domain causality test finds evidence supporting causality running from relative oil price to real exchange rate in the long run.

The main advantage of frequency domain method is to be able to analyze the whole period into different frequencies and it gives more robust results than the others. In this context, when we interpret the results of frequency domain test, these results are unexpected outcomes taking account of the dependence on imported energy. As remembered, while Hungary's energy dependency is higher than the dependency of Czech Republic and Poland, relative oil price shock does not affect the real exchange rate of Hungary. On the other hand, despite of low energy import dependency, the real oil price shocks would cause to fluctuations in real exchange rate in the long run in the case of Czech Republic and Poland. All these results conclude that the quantity of import oil is more significant than energy dependency in determination of effect of oil price on exchange rate. Although Hungary is more import energy dependent, the amount of oil imported from Russia is relatively lower than the amount of Czech Republic and Poland. It was only 4.900 TOE, while Czech Republic's and Poland's one were 8.800 and 21.000 TOE in 2004, respectively. Besides, the share of oil in total imported energy was relatively lower in Hungary. The ratio was 31% in 2004, while it was 55% and 72% in Czech Republic and Poland, respectively. This can be concluded as another energy source gas which has higher share in total energy import (55%) might have higher effect on exchange rates in the Hungarian economy. Another question concluded from the results is that whether the Czech Republic and Poland will be better of after a switch to a fully flexible exchange rate regime. Switch

from managed exchange rate to full floating exchange rate regime might reduce the interaction between relative oil price and real exchange rates.

Another important implication obtained from results is that the causality relationship running from real exchange rate to relative oil price in Czech Republic may occur only in the long run. This result supports the conclusions of Coudert, Mignon, and Penot (2007). According to them, price elasticity of oil supply and demand differs according to length of period and the longer periods allow to increasing price elasticities in oil supply and demand. Consequently, effects of real exchange rate increase on the long run. According to results, policymakers have to take into account oil price fluctuations in order to reduce exchange rate volatility in Czech Republic and Poland in the long run.

The results for Czech Republic obtained from frequency domain causality analysis support the third group of studies in the literature such as Huang and Tseng (2010) and Yanagisawa (2010). This result show that relative oil price and real exchange rate affect each other especially in economies for which the quantity of imported oil is high. Different from existing literature, the analysis results show that possible interaction occurs in the long run.

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