Oil Prices and Exchange Rates in Brazil, India and Turkey: Time and Frequency Domain Causality Analysis

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Abstract

This study investigates causal dynamics between crude oil prices and exchange rates in Brazil, India and Turkey by employing monthly data from the beginning of floating exchange regime to July 2011. The study benefits from the recent developments in the time series econometric analysis and carries out time domain causality tests (linear causality, non-linear causality, volatility spillover) and frequency domain causality test. Findings show that results from frequency domain causality test are slightly different from than those from time domain causality methods. The frequency domain analysis provides evidence on bi-directional causality in India and uni-directional causality from real exchange rates to real oil price in Turkey and Brazil.

Key Words: Oil Prices, Exchange Rates, Frequency Domain Causality Analysis

Jel Classification Codes: C32, F31, F32, Q43

Brezilya, Hindistan ve Türkiye’de Petrol Fiyatları ve Döviz Kuru: Zaman ve Frekans Dağılımı Nedensellik Analizleri

Özet

Bu çalışma, esnek döviz kuru rejiminin başlamasından Temmuz 2011 dönemine ait aylık verileri kullanarak Brezilya, Hindistan ve Türkiye’de ham petrol fiyatları ile döviz kurları arasındaki nedensellik dinamiklerini irdelemektedir. Bu çalışma zaman serisi ekonometrisindeki yeni gelişmelerden faydalanmakta ve zaman dağılımı nedensellik testleri (lineer nedensellik, doğrusal olmayan nedensellik, oynaklık taşma) ile frekans dağılımı nedensellik testi uygulamaktadır. Frekans dağılımı nedensellik testi sonuçlarının zaman dağılımı nedensellik testleri sonuçlarından farklılaştığı görülmektedir. Frekans dağılımı analizine göre, Hindistan için değişkenler arasında çift yönlü nedensellik bulunurken Türkiye ve Brezilya için reel döviz kurundan petrol fiyatlarına tek yönlü nedensellik bulunmaktadır.

AnahtarKelimeler: Petrol fiyatları, Döviz Kuru, Frekans Dağılımı Nedensellik Analizi

1. Introduction

Brazil, The Russian Federation (Russia hereafter), India and People’s Republic of China (China hereafter) –known as the BRIC countries-, are the fastest growing and largest emerging market economies. The BRIC countries account for more than 40 percent of the world’s population and 17 percent of the world total income. They are expected to be placed in the top 10 largest economies by 2020 (Goldman Sachs, 2003) and to be the most important economies followed by USA which would be in the fifth place in 2050 (de Paula, 2007). Turkey is seen to be able to join the BRIC countries because of not only her stable growth during the last decade but also potential(s) for economic development. Economic development process and institutional transformation in Turkey have similar directions as in the BRIC countries. Since the Turkish economy and its economic structure have similarities with those of the BRIC countries, the acronym of these countries would be BRIC-T.

Since the early 1980s, the BRIC-T countries have conducted the trade-oriented growth model. Liberalization, market friendly policies such as privatization, trade liberalization, stimulus to foreign direct investment, financial liberalization, social security reform and price stabilization are some of institutional changes in the process of integration to the world economy which BRIC-T countries experienced. Besides, exchange rate policy is at the center of the trade-oriented development strategy in order to increase export and to cope with trade deficits. In this context, Brazil, India and Turkey shifted from fixed to floating exchange rate regime different from Russia and China. While the People’s Bank of China operates managed floating exchange rate regime since 2005 (PBC, 2006), foreign currency trading takes place via Russia’s main stock exchange, MICEX-RTS (Lainela and Ponomarenko, 2012).

The Reserve Bank of India implemented currency peg until 1993 to ensure stability of the Rupee. After March of 1993, the market determined exchange rate regime was introduced by the Bank (Dua and Ranjan, 2010). Brazil and Turkey have shifted to floating exchange rate regime later than India. Although the Brazilian government was successful in implementing the stabilization program including fiscal and financial policies, loss of confidence in the economy and international turmoil culminated with the Russian moratorium in August 1998 induced large capital flight from Brazil. Following strong pressures on foreign exchange reserves, the Central Bank of Brazil was forced to abandon the crawling peg to the dollar. After a brief attempt to conduct a controlled devaluation, the exchange rate was forced to float in January 15 (Bogdanski et al., 2000). The Central Bank of Turkey experienced similar process at just the beginning of 2000s. Aftermath the February 2001 crisis -the most destructive economic crisis since 1945- the government decided to adopt floating exchange rate regime in Turkey (Nazlioglu, in press)[12].

Energy demand is another important issue in emerging market economies. The total energy demand and oil demand in the world increased 5,6 % and 3,1 % in 2010, respectively. The growth rate of energy demand was higher than the total economic growth in the world economy (Turkish Petroleum Corporation, 2011). According to report of the Turkish Petroleum Corporation in 2011, emerging market economies dominate the total demand. Among emerging market economies, Brazil and India have already among the first ten economies which demands highest amount of oil. While India is in the fourth place behind Japan, Brazil is in the seventh place. Brazil and India demand more than 5 million barrel in a day, and their share in the world oil demand is respectively 3.1 % and 3.8 %. Although Turkey does not have any significant role in oil production, it imports more than 1 % of total production in the world. According to World Energy Outlook (2007), India overtakes Japan to become the world's third-largest net importer, after the United States and China before 2025. In this context, the share of imports in oil demand climbs to 90 % in 2030. Similarly, Brazil has increasing energy demand. In this context, the country imports 80 % of its oil and 40 % of its foreign exchange was used to pay for that imported oil (Fichera and Kueter, 2006). Similarly, Turkey imports a large part of its oil demand. Although natural gas is an alternative energy source for Turkey, oil demand increases also in 2010.

Brazil, India and Turkey by shifting from fixed to floating exchange rates and by increasing oil demand provide room to concentrate on examining the nature of causal linkages between oil prices and exchange rates. Determining the direction of causality between oil prices and exchange rates deepens our insights for better understanding the dynamics of exchange rates. Thereby, it provides information for policy makers in designing sound trade and monetary policies in economic development process. A fluctuating exchange rate impairs on economic growth (Rickne, 2009). According to Bagella et al. (2006), the amount of capital formation would reduce due to permanent fluctuations in exchange rate. Reduction in the volume of capital formation has negative impacts on investments in especially developing countries which need capital inflow in order to finance investments. Serven and Solimano (1993) emphasize that fluctuations stemming from volatile oil prices are damaging to the non-oil sector and to capital formation. In that respect, the determination of causality presents important information which plays crucial role to prevent exchange rate fluctuations stemming from oil price fluctuations. By determining the extent to which they are exposed to the exchange rate risk, traders also benefit from such information in international trade. Besides, financial market actors, speculators, and global

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[12] We refer an interested to Nazlioglu (in pres) for an overview of Turkish trade and exchange rate policies.

investors could be able to identify portfolio diversification options in exchange rate markets.

This study examines the dynamic relationships between oil prices and exchange rates in Brazil, India and Turkey by employing monthly data from the beginning of floating exchange regime in each country to July 2011. The causal relationships are identified by the multiple testing approaches. In that respect, we employ time domain causality tests - bootstrap process-based Toda-Yamamoto linear causality test developed by Hacker and Hatemi-J (2006), non-linear causality test developed by Diks and Panchenko (2006), and causality in variance (i.e., volatility spillover) test developed by Hafner and Herwatz (2006)- and frequency domain causality test developed by Breitung and Candelon (2006). Empirical findings imply that while the time domain causality tests do not support evidence on uniform conclusion, frequency domain analysis shows bi-directional causality for India and uni-directional causality from exchange rates to oil prices in Turkey and Brazil.

The time domain causality tests produce a single test statistic for the interaction amongst the variables in concern. The frequency domain methodology generates tests statistics at different frequencies across spectra and thereby it provides flexibility to examine the direction of causality between oil prices and exchange rates in different time periods. 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 tend to differentiate from short- to long-run (Coudert et al., 2008). Even though the causal linkages between oil prices and financial variables in Brazil, India and Turkey has been examined to some extent, there is still a need to investigate the dynamics between oil prices and exchange rates within the context of rigorous econometric methods to better understanding the behavior of financial markets. By incorporating the recent developments in the causality analysis, this study contributes to the literature and provides new and fresh evidences that can be utilized in policy analysis and investment strategies.

The rest of the paper is organized as follows. Section 2 summarizes the literature on the oil prices and exchange rate nexus, section 3 outlines econometric methodology, section 4 describes data, section 5 interprets empirical results, and finally section 6 provides concluding remarks.

2. Background and Literature Review

Shifting from fixed to flexible exchange rate system creates volatilities in exchange rates which lead to question of which factors drive exchange rates as well as its volatility. The driving forces of exchange rate fluctuations have been highly debated for the past four decades. The dynamics of exchange rates have been attributed to monetary factors (Dornbusch, 1980 ; Branson 1981), real macro economic variables (Pindyck and Rotemberg 1990; Bergstrand, 1991; Faruquee, 1995; Clarida and Gali, 1994; Mark and Choi, 1997; Chinn, 1999) as well as resource endowments, change in terms of trade and productivity differentials relative to country's trading partners (Zalduendo; 2006). Besides, the behaviors of exchange rates are also attributed the change in oil prices that is thought to be an important determinant of exchange rates. Golub (1983) elucidated the effect of oil prices on exchange rates via macroeconomic flows, current account balance, and savings. Accordingly, a positive oil price shock induces wealth transfer between oil exporting and importing countries via differences in current account balances. The reallocation of wealth among the countries influences exchange rates via differentials in portfolio preferences of countries. Krugman (1983a and 1983b) argues that exchange rates differentiate due to import preferences and investment decisions of oil exporting countries in the case of oil price increases.

Since the focus of this study is on the oil prices and exchange rates relation, we herewith concentrate on reviewing the empirical studies in this regard and summarize the literature. We classified the literature into four groups. The first group of studies supports evidence on causality running from oil prices to exchange rates. Amano and van Norden (1998) for the U.S.A., Chaudhuri and Daniel (1998) for sixteen OECD countries, Aleisa and Dibooglu (2002) for Saudi Arabia, Spatafora and Stavrev (2003) for Russia, Akram (2004) for Norway, Kutan and Wyzan (2005) for Kazakhstan, Zalduendo (2006) for Venezuela, Issa et al. (2006) for Canada, Olomo and Adejumo (2006) for Nigeria, Benassy-Quere et al. (2007) for China, Chen and Chen (2007) for G7 countries, Oomes and Kalacheva (2007) for Russia, Coudert et al. (2008) for U.S.A., Narayan et al. (2008) for Fiji Islands, Korhonen and Juurikkala (2009) for nine OPEC countries, Nikbakht (2010) for seven OPEC countries, Hasanov (2010) for Azerbaijan, Dawson (2003) and Mendez-Carbajo (2011) for Dominic Republic, Basher et al. (2011) for China, India and Brazil and Lizardo and Mollick (2010) for Canada, Mexico, Norway and Russia as oil exporting countries and for Denmark, Japan, Sweden, the United Kingdom and the Euro area countries as exporting countries and reached similar results with Amano and van Norden (1998) support evidence on causal linkage from oil prices to exchange rates.

Second group of studies indicates that real exchange rate shocks induce oil price fluctuations and thereby postulates causality from real exchange rates to oil prices. Indjehagopian et al. (2000) found that variation in exchange rates have an instantaneous impact on the variations in oil prices for Holland, Germany and France. In another study for developed country context, Sadorsky (2000) does causality analysis for U.S.A. and obtained that exchange rates induces crude oil future prices that supported by Schmidbauer and Rösch (2008) and Zhang et al. (2008); Yousefi and Wirjanto (2004) for Indonesia, Iran, Nigeria and Saudi Arabia; and Yousefi and Wirjanto (2005) for Iraq, Kuwait and Venezuela.

The third group of studies finds evidence on two way causality (the feedback relation) between oil price and real exchange rates. Usama and Normee (2009) imply that there is bi-directional causality between variables in the short run in United Arabic Emirates. Huang and Tseng (2010) investigate the relationship between oil price and nominal exchange rate by using different kind of oil types and find bi-directional causality for U.S.A. Yanagisawa (2010) examines the relationship for U.S.A. and implies that bi-directional causality is valid in 2008, but causality running from exchange rate to oil price disappears in 2010. Jahan-Parvar and Mohammadi (2008) find out bi-directional causality for Gabon, Indonesia, Nigeria and Saudi Arabia.

The fourth group of studies indicates that there is no causal relationship (the neutrality) between variables, implying that oil price and exchange rates do not provide a predictive power in forecasting feature values of each other. The empirical evidence implying neutrality between oil prices and exchange rates is supported by Bjorvik et al. (1998), Habib and Kalamova (2007) and Bjornland and Hungnes (2008) for Norway, Huang and Gou (2007) for China, Habib and Kalamova (2007) for Saudi Arabia, Wu et al. (2011) for U.S.A; Mohammadi and Jahan Parvar (2010) for thirteen oil exporting countries; and Jahan-Parvar and Mohammadi (2008) for Algeria, Bahrain, Kuwait and Mexico.

3. Econometric Methods

3.1. Time domain causality test

3.1.1. 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 (Lütkepohl, 2004: 148). The Toda and 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.

The standard Granger causality analysis requires estimating a VAR (*p*) model in which *p* is the optimal lag length(s). In the TY procedure, the following VAR (*p*+*d*) model is estimated that *d* is the maximum integration degree of the variables.

$$y_t = v + A_1 y_{t-1} + \cdots + A_p y_{t-p} + \cdots + A_{p+d} y_{t-(p+d)} + \mu_t . \tag{1}$$

where y_t is vector of k variables, v is a vector of intercepts, μ_t is a vector of error terms and A is the matrix of parameters. The null hypothesis of no-Granger causality against the alternative hypothesis of Granger causality is tested by imposing zero restriction on the first p parameters. The so-called modified Wald (MWALD) statistic has asymptotic chi-square distribution with p degrees of freedom irrespective of the number of unit roots and of the cointegration relations.

Hacker and Hatemi-J (2006) investigate the size properties of the MWALD test and find that the test statistic with asymptotic distribution poorly performs in small samples. Monte Carlo simulation of Hacker and Hatemi-J (2006) shows that the MWALD test based on the bootstrap distribution has much smaller size distortions than those of the asymptotic distribution. Hacker and Hatemi-J (2006) extends the TY approach based on the bootstrapping method developed by Efron (1979) [13]. In this new approach that is so-called the leveraged bootstrap Granger causality test, the MWALD statistic is compared with the bootstrap critical value instead of the asymptotic critical value.

3.1.2. Nonlinear Granger causality test

The linear Granger causality test does not account for nonlinear causal relationships among the variables. In order to test for nonlinear Granger causality, various non-parametric methods are developed. In an early study, Baek and 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, Hiemstra and 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. In what follows, following Diks and Panchenko (2006) and Bekiros and Diks (2008), we outline the details of the DP nonparametric causality test.

Testing Granger causality from one time series (X) to another (Y) is based on the null hypothesis that X does not contain additional information about Y_{t+1} which is specified as:

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[13] See Hacker and Hatemi-J (2006:1492-1493) for the details of the bootstrap method.

$$H_0: Y_{t+1}\Big|(X_t^{\ell_X};Y_t^{\ell_Y}) \sim Y_{t+1}\Big|Y_t^{\ell_Y} \qquad (2)$$

where *lx* and *ly* respectively denote the past observations (i.e., lag length) of *X* and of *Y*. By assuming $Z_t = Y_{t+1}$ and by dropping time index and lags in the equation (2), the conditional distribution of *Z* given $(X,Y)=(x,y)$ is the same as that of *Z* given $Y=y$ under the null hypothesis. Hence, the equation (2) can be restated in terms of joint distributions that the joint probability density function $f_{X,Y,Z}(x,y,z)$ and its marginal must satisfy the following condition which explicitly states that *X* and *Z* are independent conditionally on $Y=y$ for each fixed value of *y*.

$$\frac{f_{X,Y,Z}(x,y,z)}{f_Y(y)} = \frac{f_{X,Y}(x,y)}{f_Y(y)} . \frac{f_{Y,Z}(y,z)}{f_y(y)} \qquad (3)$$

Diks and Panchenko (2006) then re-specify the null hypothesis of no nonlinear Granger causality as follows:

$$q \equiv E\left[f_{X,Y,Z}(X,Y,Z)\,f_Y(Y) - f_{X,Y}(X,Y)\,f_{Y,Z}(Y,Z)\right] = 0 \qquad (4)$$

where $\hat{f}_W(W_i)$ is a local density estimator of a $\mathrm{d_w}$ – variate random vector W at $\mathrm{W_i}$ defined by $\hat{f}w(W_i) = (2\varepsilon_n)^{-d_w}(n-1)^{-1}\sum_{j\; j\neq i}\mathrm{I}_{ij}^{w}$ that $\mathrm{I}_{ij}^{w} = \mathrm{I}(\left\|W_i - W_j\right\| < \varepsilon_n)$ with the indicator function $\mathrm{I}(.)$ and the bandwidth ε_n, depending on the sample size *n*. Given this estimator, the test statistic which is a scaled sample version of q in the equation (4) is developed as:

$$T_n(\varepsilon_n) = \frac{n-1}{n(n-2)} . \sum_i \left(\hat{f}_{X,Z,Y}(X_i,Z_i,Y_i)\,\hat{f}_Y(Y_i) - \hat{f}_{X,Y}(X_i,Y_i)\,\hat{f}_{Y,Z}(Y_i,Z_i)\right) \qquad (5)$$

If $\varepsilon_n = Cn^{-\beta}(C>0, \frac{1}{4}<\beta<\frac{1}{3})$ for one lag ($\ell_X = \ell_Y = 1$), the test statistic in equation (5) satisfies:

$$\sqrt{n}\,\frac{(T_n(\varepsilon_n)-q)}{S_n} \xrightarrow{D} N(0,1)$$

where $\xrightarrow{D}$ denotes convergence in distribution and S_n is an estimator of the asymptotic variance of $T_n(.)$ Accordingly, the DP test statistic in the equation (5) for nonlinear causality is asymptotically distributed as standard normal and diverges to positive infinity under the alternative hypothesis. Thereby, the statistic greater than 1.28 rejects the null hypothesis at 10 percent level of significance and supports evidence in favor of a nonlinear Granger causality.

3.1.3. Causality-in-variance (volatility spillover) test

Even though linear and nonlinear 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 is correspond to fluctuations in variance of data. Thereby, in addition to analyzing causality, it is useful to conduct causality-in-variance test to better understand price transmission mechanism 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). In examining volatility spillover between two series, the causality-variance of Cheung and Ng (1996) and Hong (2001) test which is based on cross-correlation functions (CCF) of standardized residuals obtained from univariate general autoregressive conditional heteroscedasticity (GARCH) estimations. is utilized in the applied literature on the commodity prices. However, the CCF based Portmanteau test is likely to be suffer from significant oversizing in small and medium samples when the volatility process are leptokurtic (Hafner and Herwartz, 2006). In addition to this drawback of Cheung and Ng's procedure, the results from CCF based volatility spillover testing approach is sensitive the orders of leads and lags which in turn questions the robustness of findings. To volatility spillover test of Hafner and Herwartz (2006) based on Lagrange multiplier (LM) principle overcomes the shortfalls of Cheung and Ng's method and is very practical for the empirical illustrations. Furthermore, the Monte Carlo experiment carried out in Hafner and Herwartz (2006) indicates that the LM approach is more robust against leptokurtic innovations in small samples and the gain from carrying the LM test increases with sample size. The results further show that an inappropriate lead and lad order choice in the CCF test distorts its performance and thereby leads to the risk of selecting a wrong order of the CCF statistic. In what follows, we briefly explain the details of Hafner and Herwartz (2006) causality in variance test.

In the Hafner and Herwartz (2006) approach, testing for causality in variance is based on estimating univariate GARCH models. The null hypothesis of non causality in variance between two return series is described as follows:

$$H_0 : Var\left(\varepsilon_{it} \middle| F_{t-1}^{(j)}\right) = Var\left(\varepsilon_{it} \middle| F_{t-1}\right) \qquad j = 1,...,N,\ i \neq j \qquad (6)$$

where $F_t^{(j)} = F_t \setminus \sigma(\varepsilon_{j\tau}, \tau \leq t)$ and ε_{it} is the residuals from GARCH model. The following model is considered to test for the null hypothesis.

$$\varepsilon_{it} = \xi_{it}\sqrt{\sigma_{it}^2 g_t}, \qquad g_{it} = 1 + z_{jt}'\pi, \quad z_{jt} = \left(\varepsilon_{t-1}^2, \sigma_{t-1}^2\right)' \qquad (7)$$

where conditional variance $\sigma_{it}^2 = \omega_i + \alpha_i \varepsilon_{it-1}^2 + \beta_i \sigma_{it-1}^2$ and ξ_{it} denotes the standardized residuals of GARCH model**.** In equation (7), the sufficient condition for equation (1) is $\pi = 0$ which ensures that the null hypothesis of non causality in variance $H_0 : \pi = 0$ is tested against the alternative hypothesis $H_1 : \pi \neq 0$. The score of the Gaussian log-likelihood function of ε_{it} is given by $x_{it}\left(\xi_{it-1}^2\right)/2$ where the derivatives $x_{it} = \sigma_{it}^{-2}(\partial \sigma_{it}^2 / \partial \theta_i)$ that $\theta_i = (\omega_i, \alpha_i, \beta_i)'$. Hafner and Herwartz (2006) propose the following LM test in order to determine the volatility transmission between the series:

$$\lambda_{LM} = \frac{1}{4T}\left(\sum_{t=1}^{T}(\xi_{it}^2 - 1)z'_{jt}\right)V(\theta_i)^{-1}\left(\sum_{t=1}^{T}(\xi_{it}^2 - 1)z_{jt}\right) \tag{8}$$

where

$$V(\theta_i) = \frac{\kappa}{4T}\left(\sum_{t=1}^{T} z_{jt}z'_{jt} - \sum_{t=1}^{T} z_{jt}x'_{it}\left(\sum_{t=1}^{T} x_{it}x'_{it}\right)^{-1}\sum_{t=1}^{T} x_{it}z'_{jt}\right), \quad \kappa = \frac{1}{T}\sum_{t=1}^{T}(\xi_{it}^2 - 1)^2$$

The asymptotic distribution of test statistic in equation (8) will depend on the number of misspecification indicators in z_{jt}. Since there are two misspecification indicators in λ_{LM}, the test has an asymptotic chi-square distribution with two degrees of freedom.

3.2. 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, which is expected to be valid at all points in the frequency distribution. 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 (Ciner, 2011). Hence, it seems to be meaningful to carry out frequency domain causality to better understand temporary and permanent linkages between oil prices and exchange rates in the BRIC-T countries.

To test for causality based on frequency domain, Geweke (1982) and Hosoya (1991) defined two-dimensional vector of time series $z_t = [x_t, y_t]'$ and z_t has a finite-order VAR;

$$\Theta(L)z_t = \varepsilon_t \tag{9}$$

where $\Theta(L) = I - \Theta_1 L - ... - \Theta_p L^p$ and lag polynomial with $L^k z_t = z_{t-1}$. Then Granger causality at different frequencies is defined as;

$$M_{y\to x}(\omega) = \log\left[\frac{2\pi f_x(\omega)}{|\psi_{11}(e^{-i\omega})|^2}\right] = \log\left[1 + \frac{|\psi_{12}(e^{-i\omega})|^2}{|\psi_{11}(e^{-i\omega})|^2}\right] \tag{10}$$

if $|\psi_{12}(e^{-i\omega})|^2 = 0$ that y does not cause x at frequency ω. If components of z_t are I(1) and cointegrated, then the autoregressive polynomial $\Theta(L)$ has a unit root. The remaining roots are outside the unit circle. Extracting z_{t-1} from both sides of equaiton 9 gives;

$$\Delta z_t = (\Theta_1 - I)z_{t-1} + \Theta_2 z_{t-2} + ... + \Theta_p z_{t-p} + \varepsilon_t = \tilde{\Theta}(L) z_{t-1} + \varepsilon_t \tag{11}$$

where $\tilde{\Theta}(L) = \Theta_1 - I + \Theta_2 L + ... + \Theta_p L^p$ (Breitung and Candelon, 2006). Geweke (1982) and Hosoya (1991) proposed a causality measure at a particular frequency based on a decomposition of the spectral density. Breitung and Candelon (2006) who has using a bivariate vector autoregressive model propose a simple test procedure that is based on a set of linear hypothesis on the autoregressive parameters. Breitung and Candelon (2006) assume that ε_t is white noise with $E(\varepsilon_t) = 0$ and $E(\varepsilon_t, \varepsilon_t') = \Sigma$, where Σ is positive definite. Let G be the lower triangular matrix of the Cholesky decomposition $G'G = \Sigma^{-1}$ such that $E(\eta_t \eta_t') = I$ and $\eta_t = G\varepsilon_t$. If the system is stationary, let $\phi(L) = \Theta(L)^{-1}$ and $\psi(L) = \phi(L)G^{-1}$ the MA representation;

$$z_t = \phi(L)\varepsilon_t = \begin{pmatrix} \phi_{11}(L) & \phi_{12}(L) \\ \phi_{21}(L) & \phi_{22}(L) \end{pmatrix} \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{pmatrix} = \begin{pmatrix} \psi_{11}(L) & \psi_{12}(L) \\ \psi_{21}(L) & \psi_{22}(L) \end{pmatrix} \begin{pmatrix} \eta_{1t} \\ \eta_{2t} \end{pmatrix} \tag{12}$$

Let we can use this representation for the spectral density of x_t;

$$f_x(\omega) = \frac{1}{2\pi}\{|\psi_{11}(e^{-i\omega})|^2 + |\psi_{12}(e^{-i\omega})|^2\} \tag{13}$$

Breitung and Candelon (2006) investigate the causal effect of $M_{y\to x}(\omega) = 0$ if $|\psi_{12}(e^{-i\omega})|^2 = 0$. The null hypothesis is equivalent to a linear restriction on the VAR coefficients. $\psi(L) = \Theta(L)^{-1}G^{-1}$ and $\psi_{12}(L) = -\frac{g^{22}\Theta_{12}(L)}{|\Theta(L)|}$, with g^{22} as the lower diagonal element of G^{-1} and $|\Theta(L)|$ as the determinant of $\Theta(L)$, it follows y does not cause at frequency ω if

$$|\Theta_{12}(e^{-i\omega})| = \left| \sum_{k=1}^{p} \theta_{12,k} \cos(k\omega) - \sum_{k=1}^{p} \theta_{12,k} \sin(k\omega) i \right| = 0 \tag{14}$$

with $\theta_{12,k}$ denoting the (1,2)-element of Θ_k. Thus for $|\Theta_{12}(e^{-i\omega})| = 0$,

$$\sum_{k=1}^{p} \theta_{12,k} \cos(k\omega) = 0 \tag{15}$$

$$\sum_{k=1}^{p} \theta_{12,k} \sin(k\omega) = 0 \tag{16}$$

Breitung and Condelon's (2006) applied to linear restrictions (14) and (15) for $\alpha_j = \theta_{11,j}$ and $\beta_j = \theta_{12,j}$. Then the VAR equation for x_t can be implied as

$$x_t = \alpha_1 x_{t-1} + \ldots + \alpha_p x_{t-p} + \beta_1 y_{t-1} + \ldots + \beta_p y_{t-p} + \varepsilon_{1t} \tag{17}$$

and the null hypothesis $M_{y\to x}(\omega) = 0$ is equivalent to the linear restriction with $\beta = [\beta_1, \ldots, \beta_p]'$

$$H_0: \quad R(\omega)\beta = 0 \tag{18}$$

and

$$R(\omega) = \begin{bmatrix} \cos(\omega) & \cos(2\omega) & \ldots & \cos(\mathrm{p}\omega) \\ \sin(\omega) & \sin(2\omega) & \ldots & \sin(\mathrm{p}\omega) \end{bmatrix} \tag{19}$$

The causality measure for $\omega \in (0, \pi)$ can be tested with the conventional F-test for the linear restrictions imposed by Eq.(15) and Eq.(16). The test procedure follows an F- distribution with (2, T-2p) degrees of freedom.

4. Data

In this study, we employ real exchange rate and real oil price in order to investigate the interaction between variables and the time period starts with the beginning of the floating exchange rate regime in each country. In this regard, the data span differentiates among countries. Accordingly, we employ monthly data from January 1999 for Brazil, March 1993 for India and February 2001 for Turkey to July 2011. The exchange rate 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. According to purchasing power parity definition, the real exchange rate is defined as the nominal exchange rate that is adjusted by the ratio of the foreign price level to the domestic price level (Kipici and Kesriyeli, 1997). In this respect, we calculate the real exchange rate according to purchasing power parity theory. In order to obtain the real 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. We calculate real oil price for each country by employing World Oil price index obtained by using four different oil price indexes. All the variables are complied from International Financial Statistics and expressed in natural logarithm.

The descriptive statistics of time series are reported in table 1. It seems that the data characteristics are slightly different in each country. The coefficient of variation as a simple measurement for volatility implies that the real oil prices are more volatile than real exchange rates that can be attributed to the oil price surges during the recent years. The variables appear to have typical characteristics of financial series with excess kurtosis and negative skewness.

Table 1: Descriptive statistics

Country	Period	Variable	Mean	Std.Dev.	CV	Skewness	Kurtosis
Brazil	January 1999-July 2011	ROP	3.787	0.576	0.152	-0.098	2.069
		RER	4.644	0.234	0.0503	0.03	2.073
		RER	4.554	0.245	0.053	-0.493	2.227
India	March 1993-July 2011	ROP	3.482	0.660	0.189	0.364	1.874
		RER	3.780	0.119	0.031	-1.222	3.844
		RER	4.715	0.071	0.015	-0.134	1.495
Turkey	February 2001-July 2011	ROP	3.923	0.514	0.131	-0.163	1.889
		RER	4.666	0.273	0.058	0.856	2.686

Notes: CV (coefficient of variation) is the ratio of standard deviation to mean. Descriptive statistics are for log return series. ROP: real oil prices, RER: real exchange rates.

5. Empirical Findings

Before proceeding to the identification of causality between the real oil prices and the real exchange rates, it is necessary to determine integration degree of variables. In that respect, we employ a battery of the unit root tests developed by Dickey and Fuller (1979 and 1981) (henceforth ADF), Phillips and Perron (1988) (henceforth PP), Elliot et al. (1996) (henceforth DF-GLS), and Kwaitkowski et al. (1992) (henceforth KPSS). The results from the unit root tests in table 2 show that ADF, PP and DF-GLS test do not reject the null of a unit root for the levels of the exchange rates and the oil prices in all the countries. When the ADF, PP and DF-GLS tests are applied to the first differences of the variables, the results indicate that all variables are stationary in each country. Consistent with these results, the KPSS test for the null hypothesis of stationary shows that the variables are stationary in the first difference form. The unit root analysis thereby implies that the variables are integrated of order one. Accordingly, the maximum integration order (d) of the variables equal to one in the TY procedure and the series in the first difference will be used in the DP.

Table 2: Results for unit root test

	Country		ADF	DF-GLS	PP	KPSS
Level						
Intercept	Brazil	ROP	-2.092 (1)	0.322(1)	-1.888 (5)	1.377
		RER	-0.594 (0)	-0.666(0)	-0.711 (2)	1.101
	India	ROP	-0.645 (1)	0.046(1)	-0.598 (4)	1.761
		RER	0.106 (3)	1.026(3)	0.345 (5)	1.117
	Turkey	ROP	-1.324 (1)	-0.388(1)	-1.101 (4)	1.183
		RER	-2.245 (4)	-0.737(2)	-1.261 (1)	1.161
Intercept and Trend	Brazil	ROP	-3.585 (1)**	-2.47(1)	-3.292 (5)	0.105 ***
		RER	-2.587 (0)	-1.452(0)	-2.729 (3)	0.27***
	India	ROP	-3.208 (1)**	-2.311(1)	-3.134 (5)	0.212***
		RER	-0.973 (3)	-1.31(3)	-0.711 (5)	0.39***
	Turkey	ROP	-2.94 (1)	-2.881(1)	-2.778 (4)	0.175***
		RER	-1.905 (4)	-2.396(4)	-2.129 (3)	0.271***
First-difference						
Intercept	Brazil	ROP	-9.322 (0)***	7.701(0)***	-9.356(2)***	0.068***
		RER	-11.67 (0)***	-1.088(2)	-11.67(0)***	0.188***
	India	ROP	-11.50 (0)***	-11.43(0)***	-11.42(1)***	0.078***
		RER	-6.87 (2)***	-6.729(2)***	-11.63(2)***	0.269***
	Turkey	ROP	-7.939 (0)***	-4.086(1)***	-7.988(2)***	0.04***
		RER	-5.974 (3)***	-1.122(2)	-8.425(5)***	0.091***
Intercept and Trend	Brazil	ROP	-9.329 (0)***	-8.664(0)***	-9.367(2)***	0.041***
		RER	-11.64 (0)***	-2.575(2)**	-11.64(0)***	0.044***
	India	ROP	-11.516(0)***	-11.56(0)***	-11.5 (1)***	0.029***
		RER	-6.987 (2)***	-6.629(2)***	-11.71(2)***	0.095***
	Turkey	ROP	-7.905 (0)***	-7.164(0)***	-7.954(2)***	0.042***
		RER	-6.181 (3)***	-2.087(2)**	-8.582(7)***	0.062***

Notes: The figures in the parentheses indicate the number lags of selected is based on the SBC for the ADF test; the bandwidth selected is based on Newey-West using Bartlett kernel for the PP test. ***,**, and * denote statistical significance at the 1, 5 and 10 percent level of significance, respectively.

The results from the linear causality analysis are presented in table 3. The causality statistics show that there is no causal relationship running from real oil prices to real exchange rates in any economy. Results also imply that causality runs from real exchange rate to real oil price in Brazil, contrary to findings of Basher et al. (2011). TY causality analysis finds no causality running from real exchange rate to real oil price for India and Turkey.

Table 3: Linear TY Granger causality test

Oil prices to exchange rates				
		Bootstrap critical values		
	Statistic	1%	5%	10%
Brazil	0.865	9.938	6.154	4.706
India	2.188	9.902	6.192	4.661
China	0.544	10.460	6.571	4.897
Exchange rates to oil prices				
		Bootstrap critical values		
	Statistic	1%	5%	10%
Brazil	8.308*	10.120	6.327	4.797
India	2.001	9.800	5.990	4.686
Turkey	4.216	9.962	6.261	4.708

Notes: ***, **, and * denote statistical significance at the 1, 5, and 10% level of significance, respectively. The SBC was used to determine the optimal lag lengths for VAR(p+d) models. Bootstrap critical values are obtained from 10,000 replications.

Since the linear causality methods may overlook nonlinear relations, we continue the empirical analysis with examining the nonlinear causal linkages between real oil prices and exchange rates. Following Bekiros and Diks (2008), the non-linear Granger causality analysis is carried out in two steps. The DP test is first applied to the stationary series to detect nonlinear interrelationships. In the second step, the DP test is reapplied to the filtered VAR residuals to see whether there is a strict nonlinear causality in nature. 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 nonlinear 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 nonlinear 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).

In table 4, the results from the non-linear causality show that there is a uni-directional causality from real oil prices to real exchange rates in Turkey, while the way of causality is from real exchange rate to oil price in Brazil contrary to finding of Basher et al. (2011). Findings of non-linear causality for Brazil support the result of TY causality test. On the other hand, there is no causality from real exchange rates to real oil prices in India.

Table 4: Non-linear Granger causality test

Oil prices to exchange rates				
	Raw data[a]		Residuals[b]	
	Statistic	p-value	Statistic	p-value
Brazil	1.103	0.134	0.763	0.222
India	0.081	0.467	-1.009	0.843
Turkey	1.727*	0.042	-1.018	0.845

Exchange rates to oil prices				
	Raw data[a]		Residuals[b]	
	Statistic	p-value	Statistic	p-value
Brazil	1.783*	0.037	0.407	0.341
India	0.835	0.201	-0.988	0.838
Turkey	-2.085	0.981	-1.003	0.842

Notes: ** denote statistical significance at the 5% level. [a]: the series in first differences [b]: the residuals of the VAR(p+d) models. Numbers in brackets are *p*-values. The results are based on one lag.

After determining the linear and non-linear causality between variables, we now concentrate on investigating whether there are volatility spillovers between real oil prices and real exchange rates. To this end, the Hafner and Herwartz (2006) causality-in-variance test is carried out and the results are illustrated in table 5. According to results it is clear that there is a spillover effect from the real exchange rate to real oil price only in India unlike the findings of linear and non-linear causality analyses. Causality-in-variance analysis results also points no spillover effect in Brazil and Turkey.

Table 5: Results for volatility spillover test

	Oil prices to exchange rates		Exchange rates to oil prices	
	Statistic	p-value	Statistic	p-value
Brazil	4.070	0.130	4.494	0.105
India	0.797	0.671	10.076***	0.006
Turkey	3.775	0.151	2.010	0.365

Notes: *** and * denote statistical significance at 1 and 10 percent level, respectively.

Finally, we employ Breitung and Candelon's (2006) analysis which permits to decompose the causality test statistic into different frequencies. We calculate the test statistics at a high frequency of ω_i =2.5 and ω_i =2.0 to examine short term causality, ω_i =1.00 and ω_i =1.50 to examine medium term causality and finally ω_i = .01 and ω_i = .05 to investigate long term causality. By doing so, we are able to learn both temporary and permanent relations between variables. According to results of frequency domain causality test, we imply that there is no effect of real oil prices on real exchange rate in Brazil and Turkey in any time period, while uni-directional causal relationship is valid for India in both short and long run. On the other hand, results show that the causal relationship running from real exchange rate to real oil price is valid for all the countries. In Brazil, causality appears on medium term only. On the other hand, causal relationship running from real exchange rate to real oil price is valid only on the short run in the Turkish and Indian economies. It is noteworthy that effect of exchange rates on real oil price disappears on the long run for all countries.

Table 6: Results for frequency domain causality test

Oil prices to exchange rates

	Long Term		Medium Term		Short Term	
ω_i	0.01	0.05	1.00	1.50	2.0	2.50
Brazil	0.251	0.705	2 .788	1.631	2.575	0.208
India	5.434	8.783*	0.244	1.159	6.273*	1.782
Turkey	0.385	0.459	1.031	1.176	1.039	0.698

Exchange rates to oil prices

	Long Term		Medium Term		Short Term	
ω_i	0.01	0.05	1.00	1.50	2.00	2.50
Brazil	5.405	0.366	8.821*	1.117	2.542	3.463
India	4.607	2.449	0.815	2.078	1.045	9.571*
Turkey	2.440	0.500	1.281	1.165	0.612	6.963*

Notes: The lag lengths for the VAR models are determined by SIC.

6. Conclusions

This paper investigates the interaction between real oil price and real exchange rate in Brazil, India and Turkey by employing monthly data from the beginning of floating exchange regime for each country to July 2011. In order to determine the causal linkages among the variables in question, we first employ the time domain causality tests – linear, non-linear, and volatility spillover causality tests. We also utilize frequency domain causality methodology to distinguish short and long run causal linkages.

Empirical results imply a number of key findings. While the time domain causality analysis shows different causal linkages, frequency domain causality test results imply that there is a causal relationship running from real exchange rate to real oil price on the short run for all countries. In this regard, there is a bi-directional causality in India. But the causality running from oil price to exchange rate is valid on the both short and long run. Frequency domain causality test results imply uni-directional causality running from real exchange rate to real oil price. These results also support the conclusion of Coudert et al. (2008) suggesting that there might be different causalities on different time periods.

The empirical analysis thereby indicates that the findings from the frequency domain analysis are slightly different than the time domain causality methods. The frequency domain analysis finds causality in different time frequencies and gives chance to distinguish short and long run impacts of variables on each other. According to the frequency domain approach, it is clear that there is an important interaction between real oil price and real exchange rate on different time periods for all countries. Causality running from real oil price to real exchange rate on both short and long run in India makes oil price fluctuations important for the financial market actors, speculators and traders in international market. They should take into account oil price changes in order to avoid probable looses causing from exchange rate fluctuations. On the other hand, there is a causality running from real exchange rate to real oil price on the short run in all countries. The existence of the causality from real exchange rate to real oil price on the short run could give some hints explaining the fluctuations in the price of oil.

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