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Non-linear and Asymmetric Influence of Oil Prices on Exchange Rates: Evidence from South Asia

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Non-linear and Asymmetric Influence of Oil Prices on Exchange Rates: Evidence from South Asia

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Abstract

The paper analyses the asymmetric and nonlinear effects of oil price on exchange rates of South Asian countries in time-frequency framework using wavelet technique. For empirical analysis monthly data is used for the period 1983:07–2018:06. Wavelet coherence results show that the series are in phase i.e. oil price and exchange rates are positively correlated. It suggests that oil price causes exchange rates positively. The paper also investigates the long run cointegrating and nonlinear causal association between oil price and exchange rates using Gregory and Hansen (1996) structural break cointegration technique and Diks and Panchenko (2006) nonlinear causality test. The results show that cointegration exists between oil price and exchange rates in all countries. The results of nonlinear causality show that there is bi-directional causality between oil price and exchange in Bangladesh and India and unidirectional causality from oil price to exchange rate in Pakistan and Sri Lanka. The findings provide some important recommendations to investors and policy makers.

Keywords: Oil Price; Exchange Rates; Wavelet; Cointegration; South Asia

JEL Classification: C22, F31, Q43

1. Introduction

Oil is an important energy input for economic development of a country as oil prices affect cost of production especially in oil consuming economies. Oil price affects the macroeconomy and capital markets of the countries. Large increase in oil prices result in economic recession, surge in inflation and trade deficits in oil importing countries. It also increases uncertainty and stocks and bonds value (Chaudhuri and Daniel, 1998). Oil prices also affect exchange rates of both oil producing and consuming countries (Huang and Tseng, 2010).

Like oil, exchange rate is also important for economic growth of a country as it affects tradable sector and investment level of the country. Fluctuations in real exchange rate (RER) occur mainly due to non-monetary/real shocks like oil prices, fiscal condition, productivity, labor supply, etc. Among these variables oil price fluctuations is the main variable which is responsible for RER rate fluctuations (Chaudhuri and Daniel 1998). Thus, both oil price and exchange rate are associated in a way that shocks in oil market can be transferred into exchange rate market.

Theoretically, there are different channels via which oil price can affect exchange rate i.e. terms of trade, and wealth effect (Benassy-Quere et al. 2007, Beckman and Czudaj 2013, Habib et al. 2016). According to terms of trade channel, there are two sectors (tradeable and non-tradeable) in the economy and both sectors employ a tradable input (oil) and a nontradable input (labor). If there is increase in oil price, then labor price should decrease so that tradeable sector may remain competitive. If nontradable sector is more energy intensive compared to tradable sector, then RER will appreciate and vice versa. In oil-exporting countries, high oil prices create positive terms of trade shocks, which lead to Dutch Disease hypothesis by increasing the price of the nontradable goods which appreciates domestic currency. According to Chen and Chen (2007) in oil dependent country high oil price worsens terms of trade by increasing prices of tradable goods in the domestic country relatively greater than in foreign country, it depreciates the RER of local currency. Further, to improve competitiveness the home country needs to increase nominal exchange rate, which further depreciates RER.

According to wealth transmission channel, when the oil price rises it transfers wealth from oil-consuming to oil producing countries. It appreciates (depreciates) the exchange rates of the oil-exporting (importing) countries by improving (deteriorating) their trade balance (Krugman 1983). According to Golub (1983) high oil price improves (deteriorates) current account balance of oil exporting (importing) countries. If the supply of dollars in oil exporting countries is larger than the demand of dollars in oil-importing countries, then this excess supply of dollar will depreciate dollar

and will appreciate non-dollar/foreign currencies. There is also an interest rate channel. According to Darby (1982) high oil price increases inflation. This high inflation increases domestic interest rate, which increases foreign capital inflows. This appreciates local currency.

After the oil crisis of 1973 several studies investigated the impact of oil price on different sectors of economy like GDP, stock market, inflation, investment, exchange rate, terms of trade, interest rate, etc. Some studies also examined the effect of international oil prices on exchange rates. These studies have mainly shown that high oil price appreciates (depreciates) the currencies of oil exporting (importing) countries. Next section provides literature review in detail. The existing empirical literature has mainly examined oil price-currency link for developed economies and oil-producing countries. Few authors have analyzed the case of oil dependent small open economies. Empirical literature for South Asia countries is almost scant. Due to high economic growth, population growth, modernization, urbanization, industrialization, energy consumption, oil demand and its related product is increasing in South Asia. The acceleration of economic growth in South Asia has increased its dependence on imported oil. The oil prices have affected the real economy of these countries by affecting different macroeconomic factors. Exchange rate is important channel via which oil price shock is transferred to the economy. Thus, this paper examines oil price and currency linkages in oil dependent small open economies of South Asia.

Earlier studies have used traditional econometric techniques to analyze oil price and exchange rate nexus like co-integration, Granger causality test, the vector autoregressive (VAR) model, the vector error correction model (VECM), correlation, etc. These techniques can examine only the linear effect of oil prices on exchange rate while the actual effect of oil price on exchange rate may be nonlinear and asymmetric. Further, the traditional econometric techniques require stationarity of the variables, but both oil prices and exchange rates are not stationary variables. Therefore, the present study will explore the asymmetric and nonlinear impact of oil price on exchange rates using wavelet technique. This technique also does not require stationarity of the variables.

This study has some important contributions to the literature due to several reasons. First, it will re-examine the impact of oil prices on exchange rates as previous studies have provided the inconclusive impact of oil prices on exchange rates. Second, it will examine the causal relationship in time-frequency domain as causality can differ over time and frequency. For this purpose, it will use continuous wavelets tools to investigate the effect of oil price on exchange rate. It will help to

capture nonlinear relationships among both variables. Third, the traditional linear Granger causality tests are ineffective to find nonlinear relations. Therefore, this study will use Diks and Panchenko (2006) nonlinear causality test. Fourth, it will examine oil price-currency linkages in South Asia, where only limited literature is available. Thus, this paper is an important contribution to the literature.

Remaining paper is laid out as follows. Section 2 provides review of literature. Section 3 provides oil price and exchange rate trends in South Asia. Section 4 elaborates methodology. Section 5 explains the empirical results. Conclusion is provided in final section.

2. Review of Literature

Empirically, several studies have investigated the influence of international oil prices on exchange rates. Earlier studies include Golub (1983) and Krugman (1983), which document that high oil prices may appreciate the currencies of oil exporting countries and may depreciate the currencies of oil importing countries. Later on, several other studies have also been conducted on oil price and exchange rate relationship. Amano and van Norden (1998) and Chaudhuri and Daniel (1998) assert that oil price fluctuation is an important factor of exchange rate fluctuation in US dollar after Bretton Woods system. Akram (2004) has shown nonlinear impact of oil price on exchange rate in Norway. Earlier studies have basically supported the Dutch disease hypothesis (Issa et al. 2008, Korhonen and Juurikkala 2009).

Table 1 gives the summary of the findings of the key recent studies which have explained the association between oil price and exchange rates. It is evident from the table that the studies have mixed findings for the impact of oil prices on exchange rates. In general, the studies have shown that high oil prices depreciate the currencies of oil importing countries and appreciate the currencies of oil exporting countries and have validated the Dutch disease hypothesis in oil exporting countries (Lizardo and Mollick 2010, Al-mulali and Sab 2012, Hasanov et al. 2017, Korhonen and Juurikkala 2009, Oomes and Kalcheva 2007). However, Mohammadi and Jahan-Pavar (2012) have provided limited evidence in favor of Dutch disease hypothesis. Basher et al. (2012) have shown that exchange rate of emerging economies become weak after oil price increase. Using data for 43 countries, Habib et al. (2016) have documented that there is no systematic association between oil price and exchange rates. Some studies have also shown

insignificant relationship between both variables (Habib and Kalamova 2007). According to Reboredo (2012) there is weak link between oil price and exchange rate.

These inconclusive findings are due to several reasons. First, different studies have taken different sample countries which vary in their features like oil producing, oil consuming, developing, developed, emerging countries, etc. Second, different studies have used different econometric techniques for the analysis which have yielded different results. Third, studies have used different time period, data type (panel vs time series), data frequency (monthly, quarterly, annual), etc. for the analysis. Fourth, results are also different as different studies have used different (nominal vs real) exchange rates and different oil price measures.

It is evident from the table that studies mainly concentrated on oil exporting and developed countries and ignored the analysis for small open economies. Only scarce literature is available for oil-dependent small open economies like South Asian countries. Ghosh (2011), using daily data from July 2007 to November 2008, has examined the impact of oil price shocks on Indian exchange rate. The study applied GARCH and EGARCH techniques for the analysis. The findings reveal that oil price shocks have depreciated Indian currency against US dollar. Later on, Tiwari et al. (2013a) have shown linear and nonlinear association between oil price and Indian currency. Shahbaz et al. (2015), using monthly data from February 1986 to March 2009 have examined the time–frequency relationship between oil price and exchange rate in Pakistan through wavelet technique. The findings reveal that the causality between oil price and exchange rate vary across scales. No study is available for any other South Asia country. This study will fill the gap in the literature by examining the nonlinear and asymmetric effect of oil price on exchange rates of South Asian countries by using wavelet technique. Further, Gregory and Hansen (1996) structural break cointegration test and Diks and Panchenko (2006) nonlinear causality test will also be applied for robustness analysis.

Studies have mainly used traditional econometric techniques like linear regression, correlation, cointegration, Granger causality, VAR, ARDL model, GARCH, etc. to find oil price-currency linkages. Few recent studies have used sophisticated techniques like wavelet analysis, frequency domain analysis, copulas, nonlinear techniques, etc. The traditional cointegration tests are based on the assumption that the response of exchange rate to oil price shock is symmetric. However, the response of exchange rate to oil price shocks is asymmetric. Therefore, some studies

have documented that oil price shocks have nonlinear and asymmetric impact on exchange rates (Ahmad and Hernandez 2013, Chen et al. 2013, Kisswani et al. 2018, Tiwari et al. 2013a).

Table 1: Review of Literature

Studies	Data Type(s)	Time Period	Exchange rate variable	Estimation Technique	Main Finding(s)
Habib and Kalamova (2007)	Norway, Russia, Saudi Arabia	1980Q1-2006Q2 1995Q1-2006Q2 (Russia)	REER	OLS, Johansen Cointegration, VECM	• There is long-run association between oil prices and exchange rate in Russia but not in Norway and Saudi Arabia.
Benassy-Quere et al. (2007)	USA	1974:01–2004:11	RER, REER	Cointegration, Causality	• The results show that high oil price appreciates dollar.
Chen and Chen (2007)	Panel of G7 countries	1972:01–2005:10	RER	Cointegration FMOLS, DOLS, PMG	• High oil price depreciates exchange rate in the long-run.
Huang and Guo (2007)	China	1990:01-2005:10	RER	SVAR	• Increase in oil price appreciates exchange rate in the long-run.
Narayan et al. (2008)	Fiji	11/29/2000 - 9/15/2006	NER	GARCH, EGARCH	• High oil price appreciates the Fijian dollar.
Korhonen and Juurikkla (2009)	9 OPEC countries	1975–2005	RER, REER	Pool Mean Group Estimator	• High oil price appreciates exchange rate.
Lizardo and Mollick (2010)	8 countries	Data varies for each country	NER	Johansen Cointegration	• High oil prices appreciate (depreciate) currencies of oil exporting (importing) countries.
Ghosh (2011)	India	02/07/ 2007– 28/11/2008.	NER	GARCH, EGARCH	• High oil price depreciates Indian exchange rate against US dollar. • Oil price shock has permanent effects on exchange rate volatility.
Mendez-Carbajo (2011)	Dominican	1990–2008	RER	VAR, VECM, Granger Causality	• An increase in oil price depreciates exchange rate.

Mohammadi and Jahan-Pavar (2012)	13 oil-exporting countries	1970:1- 2010:1	RER	TAR, M-TAR Cointegration	• Oil prices have a long run effect on exchange rates. • No causality is found between variables. . • There is limited evidence for Dutch disease.
Basher et al. (2012)	Emerging Economies	1988:01-2008:12	Trade-weighted exchange rate index in US dollar	SVAR	• Oil price plays a major role in determining exchange rate moments among emerging economies. • Exchange rate of emerging economies become weak upon the rise in oil prices.
Al-mulali and Sab (2012)	Panel data for 12 oil-exporting countries	2000-2010	RER	Random Effect Model	• The results show that high oil price appreciate the exchange rate.
Wu et al. (2012)	USA	02/01/1990-28/12/2009	US dollar index Futures	Copula-based GARCH	• The relationship between oil price and exchange rate is negative and has decreased after 2003.
Reboredo (2012)	USA	04/01/2000-15/06/2010	Trade Weighted Exchange Index	Correlation, Copula, ARMA, TGARCH	• There is weak dependence between oil price and exchange rate.
Turhan et al. (2013)	13 emerging economies	03/01/2003-02/06/2010	NER	VAR	• Oil price shocks have depreciated the exchange rates after global financial crisis.
Ahmad and Hernandez (2013)	12 major oil-exporting and oil-importing countries	1970:01–2012:01	RER	TAR, M-TAR	• Oil price shocks have asymmetric effects on exchange rate.
Chen et al. (2013)	Philippines	1970Q1-2011Q4	RER	Engle–Granger cointegration test, TAR, MTAR	• There is asymmetric association between oil price shocks and exchange rates.
Tiwari et al. (2013a)	India	1993:04-2010:12	REER	Wavelet	• Oil price and exchange rate are not linked at lower scale. At higher scale there is bidirectional causality between both variables.
Tiwari et al. (2013b)	Romania	1986:02–2009:03	REER	Wavelet	• Oil price has short and long run effect on exchange rate.

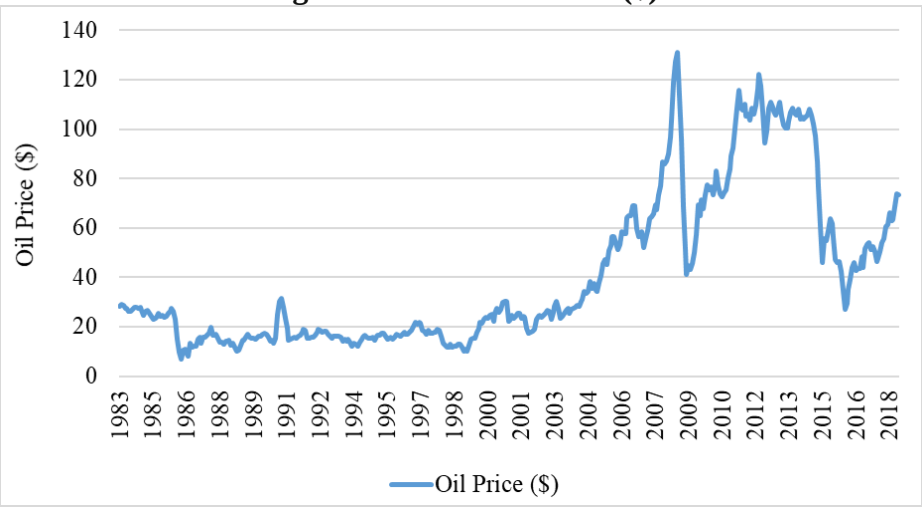
Aloui et al. (2013)	US	04/01/2000-17/02/2011	NER	Copula-GARCH	• High oil price depreciates dollar.
Brahmasrene et al. (2014)	US	1996:01-2009:12	NER	Cointegration, VAR, Granger Causality	• Oil price shock has a significant effect on exchange rate both in medium and long run.
Fowowe (2014)	South Africa	02/01/2003-27/01/2012	NER return	GARCH	• High oil price depreciates South African currency.
Bal and Rath (2015)	China, India	1994:01-2013:03	REER	Hiemstra and Jones (1994) nonlinear Granger causality test	• There is bi-directional (uni-directional) causality between oil price and exchange rate in India (China).
Bouoiyour et al. (2015)	Russia	1993Q1-2009Q4	REER	ARDL, Wavelet	• The results show that causality runs from oil price to exchange rate at lower frequency.
Pershin et al. (2016)	Botswana, Kenya, Tanzania	01/12/2003-02/07/2014	NER	Cointegration, VAR	• Oil price shock has different effect on exchange rates of these countries.
Shahbaz et al. (2015)	Pakistan	1986:02–2009:03	REER	Wavelet, ARDL	• Causality between oil price and exchange rate is different at different time scales.
Ngoma et al. (2016)	Egypt, Ghana, Nigeria, South Africa, Tunisia	1960:05-2014:04 (Egypt) 1990:01-2013:12 (Ghana) 1985:01-2013:04 (Nigeria) 1970:01-2014:04 (South Africa) 1998:01-2014:04 (Tunisia)	RER	Cointegration, Error Correction	• There is long run relationship between oil price and exchange rates. • In short run oil price appreciates exchange rates.
Su et al. (2016)	Australia, Canada, the European Union, Japan, Mexico, Norway, UK	1974:01-2015:03	RER Return	Quantile Regression	• Oil shocks have heterogeneous effects on exchange rates across quantiles.

Hasanov et al. (2017)	Azerbaijan, Kazakhstan, Russia	2004Q1–2013Q4	RER	ARDL	• Oil price appreciates exchange rates in these countries.
Kim and Jung (2017)	Currencies of 40 countries	03/01/2013-06/10/2014	NER	FDA, Copula	• High oil price depreciates most of the currencies.
Yang et al. (2017)	8 oil producing and oil consuming countries	01/01/ 1999-31/12/2014	NER	Wavelet	• Oil price negatively affects exchange rates in oil-exporting economies, while it has uncertain effect on exchange rate of oil importing countries.
Kisswani et al. (2018)	ASEAN-5	1970:Q1-2016:Q4	Growth rate of RER	Non-linear ARDL	• For some countries bi-directional and for other countries unidirectional causality is observed between oil-prices and exchange rates. • Results also show asymmetric effect for Indonesia and Malaysia

3. Trend of Oil Prices and Exchange Rates in South Asia

Figure 1 explains the pattern of crude oil prices from July 1983 to June 2018. Crude oil price was $28 in July 1983, which fell to its lowest level to $7 in 1986. It increased to $32 in October 1990, which continued to decrease and reached at $10 in February in 1999. After that it again increased and stood at $30 in October 2000 and then declined to $18 in January 2002. Then it started to increase and reached all time high to $131 in July 2008 and dropped rapidly to $41 in December 2008. Thus, during the financial crisis oil price has shown a clear structural change. After that it soared again and reached at $116 in April 2011. After 2014 oil price continued to fall and it decreased to $46 in January 2015. Drop in international oil demand, change in OPEC policies and US dollar appreciation were responsible for post-2014 oil price drop. In January 2016, oil price decreased to $27 but gradually increased throughout the year. Oil price peaked at $73 in June 2018. However, there is no significant oil price fluctuations globally. All it indicates that after 2002 due to global supply and demand factors there is unprecedented increase in oil prices.

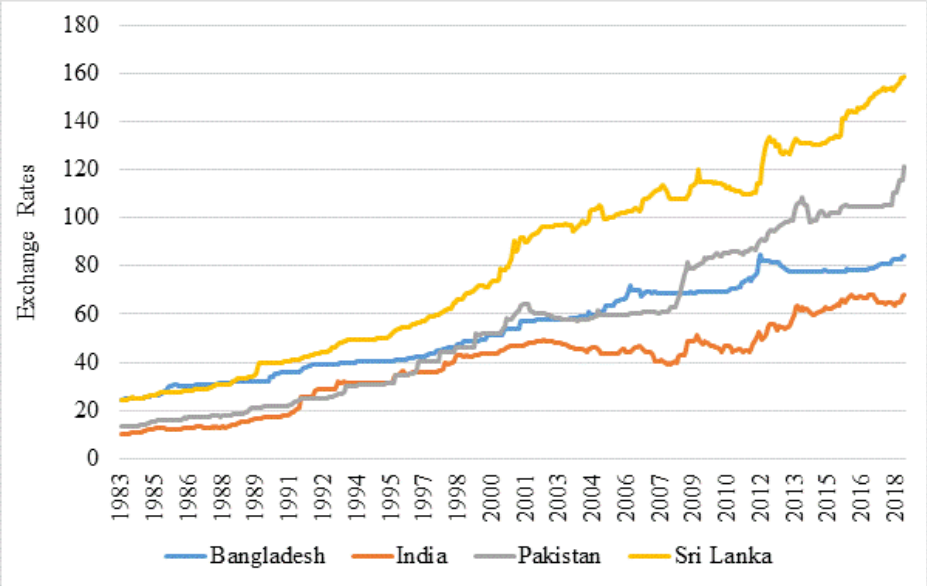
Figure 1: Crude Oil Price ($)



This oil price escalation is important for oil dependent South Asian countries as these countries continued their economic development, which also increased their oil import. Oil import which was 462 bbl/d in 1983 has increased to 4660 bbl/d in 2018 in South Asia. This oil import demand has increased significantly in India followed by Pakistan, Sri Lanka and Bangladesh. This high oil price has some important ramifications for macroeconomy in South Asian countries especially for their exchange rates. High oil price has depreciated their exchange rates via trade deficits (Figure 2). Exchange rates are expressed in direct quotations. A high numerical value of

exchange rate indicates depreciation of local currency against US dollar. Sri Lankan currency has shown largest depreciation followed by Pakistan, Bangladesh and India. It indicates that there is link between oil price and exchange rates in South Asia.

Figure 2: Exchange Rates in South Asia



4. Theoretical Framework

4.1. Continuous Wavelet Transformation (CWT)

To investigate the interdependence between oil price and exchange rate both in time and frequency, we will use wavelet technique. The continuous wavelet transformation (CWT) is specified as follows (Vacha and Barunik 2012, Rua and Nunes, 2009):

$$W_x(u,s) = \int x(t)\frac{1}{\sqrt{s}}\varphi\left(\frac{t-u}{s}\right)dt \qquad (1)$$

$W_x(u,s)$ is estimated for the wavelet $\varphi(.)$ for a specific time series. $\frac{1}{\sqrt{s}}$ is parameter to get unit variance of wavelet $||\varphi_{u,s}||^2$. $u(s)$ is location (scale dilation) parameter of the wavelet. Scale is inversely related to frequency. It implies a stretched wavelet which is suitable to detect low frequency.

Among different functional forms of wavelet, the Morlet wavelet is an important wavelet to study synchronism among time series (Goupillaud et al. 1984), which is written as

$$\varphi^M(t) = \pi^{-\frac{1}{4}} e^{i\omega_0 t} e^{-\frac{t^2}{2}} \tag{2}$$

where $\varphi^M(t)$ is Morlet wavelet function and ω_0 is central frequency of wavelet (Grinsted et al. 2004).

To measure variance at different frequency levels, wavelet power spectrum will be calculated as $|W_x(u,s)|^2$.

4.2. Wavelet Coherence (WTC)

To demonstrate the correlation between series in time-frequency space, wavelet-squared coherence is used.

$$R^2(u,s) = \frac{|S(s^{-1}W_{xy}(u,s))|^2}{S(s^{-1}|W_x(u,s)|^2)S(s^{-1}|W_y(u,s)|^2)} \tag{3}$$

S is smoothing parameter. $R^2(u,s)$ falls between 0 and 1 i.e. $0 \leq R^2(u,s) \leq 1$. Value close to zero (one) indicates weak (strong) correlation between variables.

4.3. The Phase Pattern

Wavelet coherence cannot distinguish between positive and negative dependence structure as it is squared. Therefore, to get direction of causality between series, phase difference tool is used. The phase difference $\phi_{x,y}$ between $x(t)$ and $y(t)$ is represented as follows (Aguiar-Conraria et al. 2008):

$$\phi_{x,y} = tan^{-1}\left(\frac{\Im\{S(s^{-1}W_{xy}(u,s))\}}{\Re\{S(s^{-1}W_{xy}(u,s))\}}\right) \tag{4}$$

where $\Im$ ($\Re$) is imaginary (real) part of a complex number. Two series will co-move when phase difference is zero at the specified frequency. Further, if the series are in phase (positively correlated), the arrow will be oriented to right. In this case y leads x when $\phi_{x,y} \in [0, \frac{\pi}{2}]$, and x leads y when $\phi_{x,y} \in [-\frac{\pi}{2}, 0]$. In turn, the series are in anti-phase or out of phase (negatively correlated), when the phase difference is π or $-\pi$, the arrows will be pointed to left. If $\phi_{x,y} \in$

$[-\pi, -\frac{\pi}{2}]$ then y is leading, and if $\phi_{x,y} \in [\frac{\pi}{2}, \pi]$ then x is leading. Moreover, if arrows point left and up or right and down then y leads x. If arrows point left and down or right and up then x leads y.

4.4. Wavelet Cohesion and Causality

Wavelet-based causality mesaure of Olayeni (2016) is based on Rua (2013) wavelet correlation measure. The wavelet correlation measure of Rua (2013) is expressed as

$$\rho_{xy}(s,\tau) = \frac{u\left(W_{xy}(s,\tau)\right)}{\sqrt{|W_x(s,\tau)|^2 |W_y(s,\tau)|^2}} \tag{5}$$

$\rho_{xy}(s,\tau)$ ranges between -1 and 1 i.e. $-1 < \rho_{xy}(\tau,s) < 1$. This correlation measure shows co-movements at time and frequency simultaneously. The wavelet causality measure is provided as

$$G_{x\to y}(s,\tau) = \frac{u\left(W_{xy}(s,\tau)\right) I_{x\to y}(s,\tau)}{\sqrt{|W_x(s,\tau)|^2 |W_y(s,\tau)|^2}} \tag{6}$$

where $I_{x\to y}(s,\tau)$ is an indicator function and is defined as

$$I_{x\to y}(s,\tau) = \begin{cases} 1, & if\ \phi_{xy}(s,\tau)\epsilon(0,\pi/2) \cup (-\pi,-\pi/2) \\ 0, & \text{otherwise} \end{cases} \tag{7}$$

5. Data and Empirical Results

5.1. Data and Preliminary Statistics

For empirical analysis monthly data for real oil price and real exchange rate (RER) is taken for the flexible exchange rate period from July 1983 to June 2018 for four South Asian countries namely Bangladesh, India, Pakistan and Sri Lanka. Real oil price is constructed as crude oil price of Dubai Fateh deflated by consumer price index (CPI) of US. Data of Dubai Fateh oil price (US dollar per barrel) is taken from OPEC[1]. RER is constructed as nominal exchange rate (NER) adjusted for domestic and foreign price levels (measured by CPI). NER is domestic currency per unit of foreign currency (US dollar) and is taken in direct quotation in which a high numerical value of currency indicates depreciation of local currency. Data for NER and domestic and foreign

[1] https://www.opec.org/opec_web/en/data_graphs/40.htm OPEC (2020)

(US) CPI is taken from International Financial Statistics (IFS)[2]. For empirical analysis both real oil price and RER are taken in natural logarithms. Since all variables have increasing trend, they are detrended by taking log first differences.

Table 2 gives the descriptive statistics of the data. The average value of real oil price is $0.47 per barrel, while the minimum is $0.13 and the maximum is $1.30. The standard deviation is 30.04. The RER for Bangladesh has a mean of 75.71, with a minimum of 54.46 and a maximum of 165.94 and the standard deviation is 15.50. The average real value of Indian rupee is 53.44, which ranges between 40.21 and 71.09 with the standard deviation of 7.57. Similarly, the real average value of Pakistani rupee is 81.49, which ranges between 62.36 and 109.31 with standard deviation of 9.48. The real exchange rate for Sri Lanka has a mean value of 147.09 with a minimum of 72.53 and a maximum of 203.97 and the standard deviation is 26.18. All skewness values are positive which show that the variables are skewed right. All kurtosis coefficients are also positive, which indicate that all series exhibit leptokurtic behavior. It implies that the distribution of series has larger, thicker tails compared to normal distribution. Statistically significant values of Jarque-Bera (JB) statistics show that variables do not have normal distribution. Table 3 gives the correlation values between series. It is found that oil price has statistically significant high correlation with all exchange rates, which indices that oil price and exchange are correlated in South Asia.

Table 2: Descriptive Statistics

		Real Exchange Rates			
	Real Oil Price ($)	Bangladesh	India	Pakistan	Sri Lanka
Mean	0.47	75.71	53.44	81.49	147.09
Median	0.35	73.58	53.21	79.16	149.70
Minimum	0.13	54.46	40.21	62.36	72.53
Maximum	1.30	165.94	71.09	109.31	203.97
Std. Dev.	0.27	15.50	7.57	9.48	26.18
Skewness	1.02	2.20	0.05	0.55	0.01
Kurtosis	2.97	10.16	1.69	2.63	2.16
Jarque-Bera (JB)	73.20***	1235.83***	30.16***	23.76***	12.35***
Probability (JB)	0.00	0.00	0.00	0.00	0.00

Note: *** indicates statistical significance of value at 1% level.

[2] https://data.imf.org/?sk=4C514D48-B6BA-49ED-8AB9-52B0C1A0179B IFS (2020)

Table 3: Correlation of Real Oil Price with Exchange Rates

Bangladesh	0.7867 (26.0570)***
India	0.5724 (14.2723)***
Pakistan	0.7473 (22.9990)***
Sri Lanka	0.7231 (21.4077)***

Note: *** indicates statistical significance of value at 1% level.

5.2. Continuous Wavelet Transformation (CWT) Power Spectrum

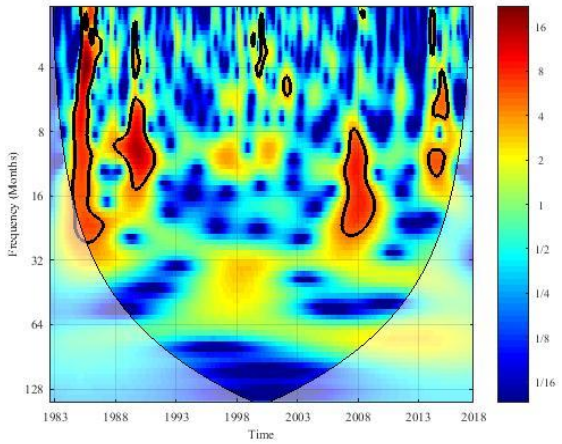
CWT power spectral plots of oil price and exchange rates are shown in Figure 3. CWT plots basically show the power/variance of the series. Oil price plot indicates that it has high fluctuations between 1984 and 1986 at 0–32 months of scale (high to medium frequency), 1988–1991 at 6–14 months of scale and 2007-2009 at 8-26 months of scale frequency.[3] Thus, oil price shows high fluctuations in three periods, but at different frequencies. In first two periods, oil price decreased globally and in the third period oil price surged and this period is also the period of 2007/08 financial crisis. Bangladesh exchange rate has strong power in short and medium run at 1–32 months of scale during 1983–1988. Volatility in Indian exchange rate is scattered throughout the time period at different frequency levels. Exchange rate in Pakistan has high fluctuations between 1995-2004 at 4-24 scales (high to medium frequency) and between 2007-2010 at 6-20 scales (high to medium frequency). There is volatility in Sri Lankan exchange between 1997-1999 at frequency level of 1-16 months.

Figure 3: CWT Power Spectrum of Oil Price and Exchange Rates

Panel A: Oil Price

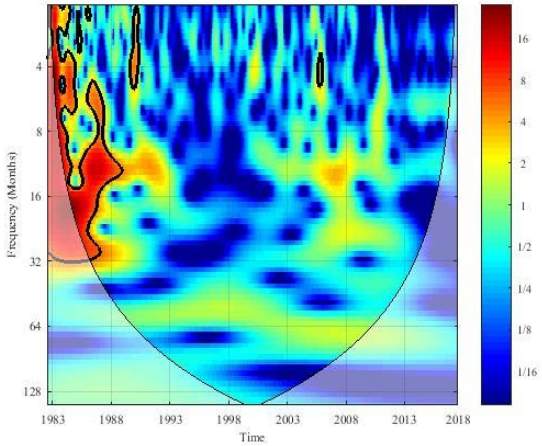
Oil Price

[3] The frequency bands are arbitrary. The first 16 months indicate high frequency, 16–32 months indicate medium and more than 32 months indicate low frequency bands.

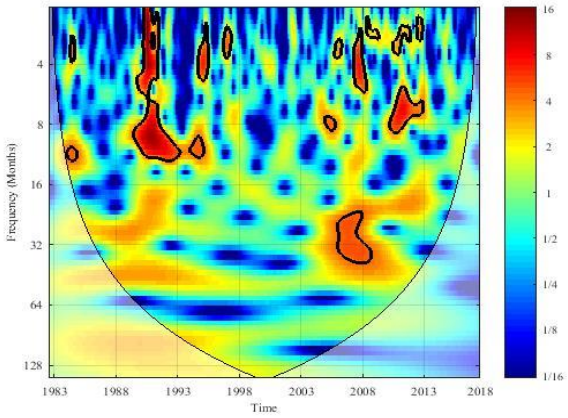


Panel B: Exchange Rates

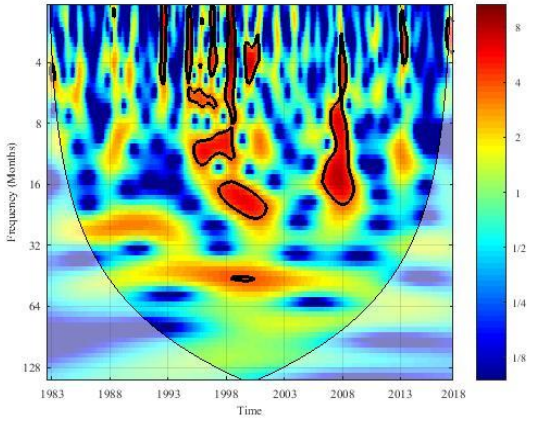
Bangladesh



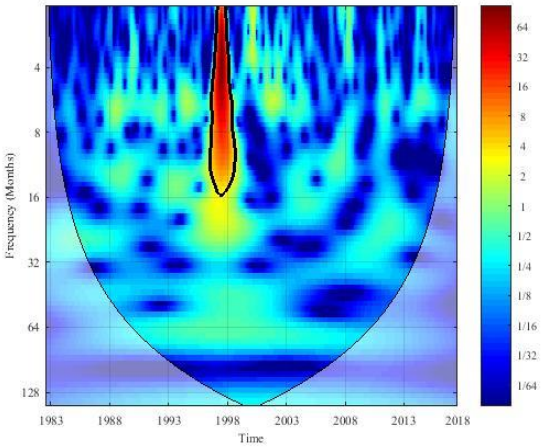
India



Pakistan



Sri Lanka



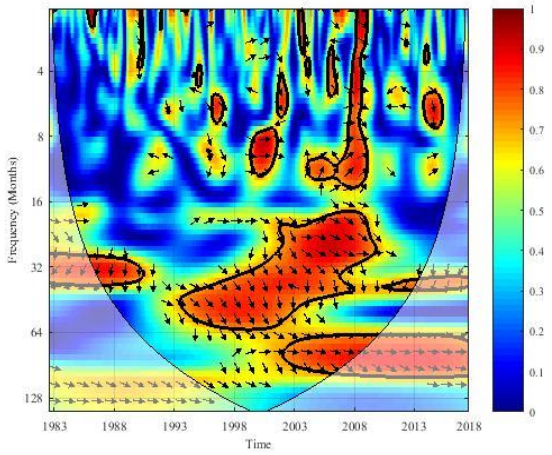
Note: Significance level at 5% is shown as thick black contour. Blue (red) color shows low (high) power. X-axis provides time period while Y-axis provides frequency (in months).

5.3. Wavelet Coherency (WTC)

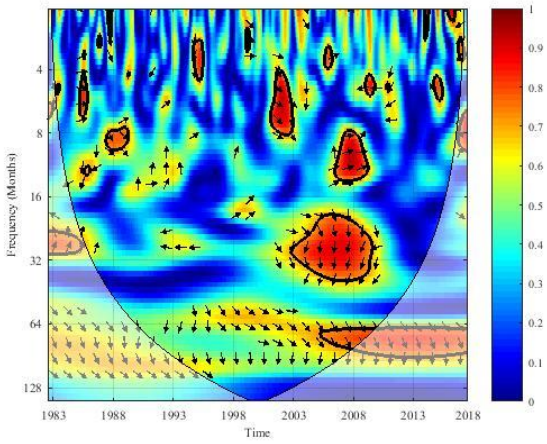
Wavelet coherency (WTC) plots of oil prices with exchange rates are depicted in Figure 4. For WTC of oil prices with exchange rate of Bangladesh, co-movements are mainly found at frequency range of 28-36 months during 1986–1990, at scale of 16-64 months during 1993–2010, and at scale of 64 onwards during 2002-2018. The arrows are mainly oriented to right thus variables have positive relationships. For India co-movements are found at different frequencies from 2000 to 2010. The main co-movement is observed during 2003-2010 at 18-40 months band. For Pakistan co-movement is found between 1995-2012 mainly at 8-16 months frequency and at 2-32 months frequency. As for as Sri Lanka is concerned there are co-movements between oil price and exchange rate at different frequency levels at different time periods but the main co-movement between both series is found at 36-68 months frequency during 1990-2010 time periods. The arrows point to right and up, it shows that oil prices cause exchange rate positively.

Figure 4: Wavelet Coherency (WTC) between Oil Prices are and Exchange Rates

Bangladesh

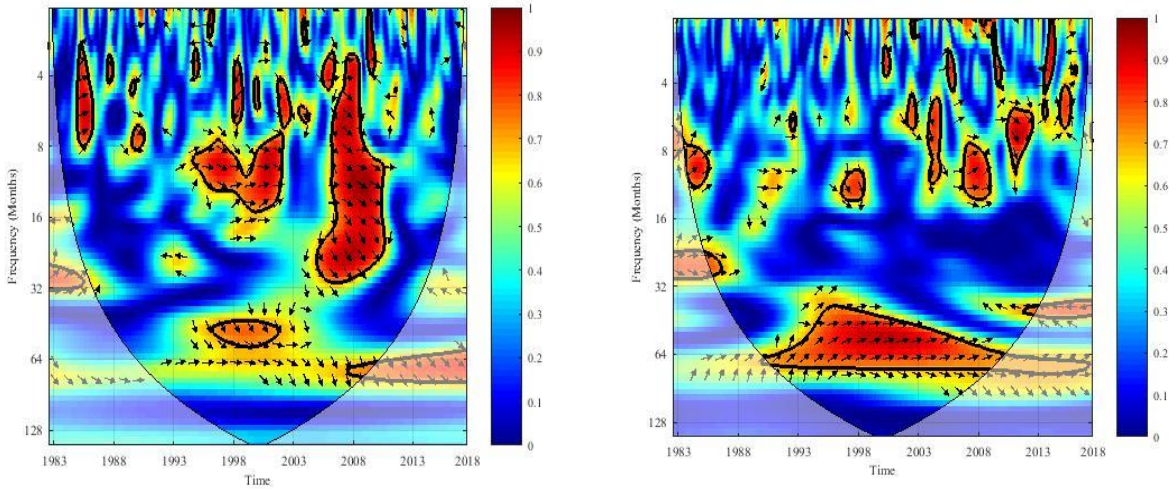


India



Pakistan

Sri Lanka

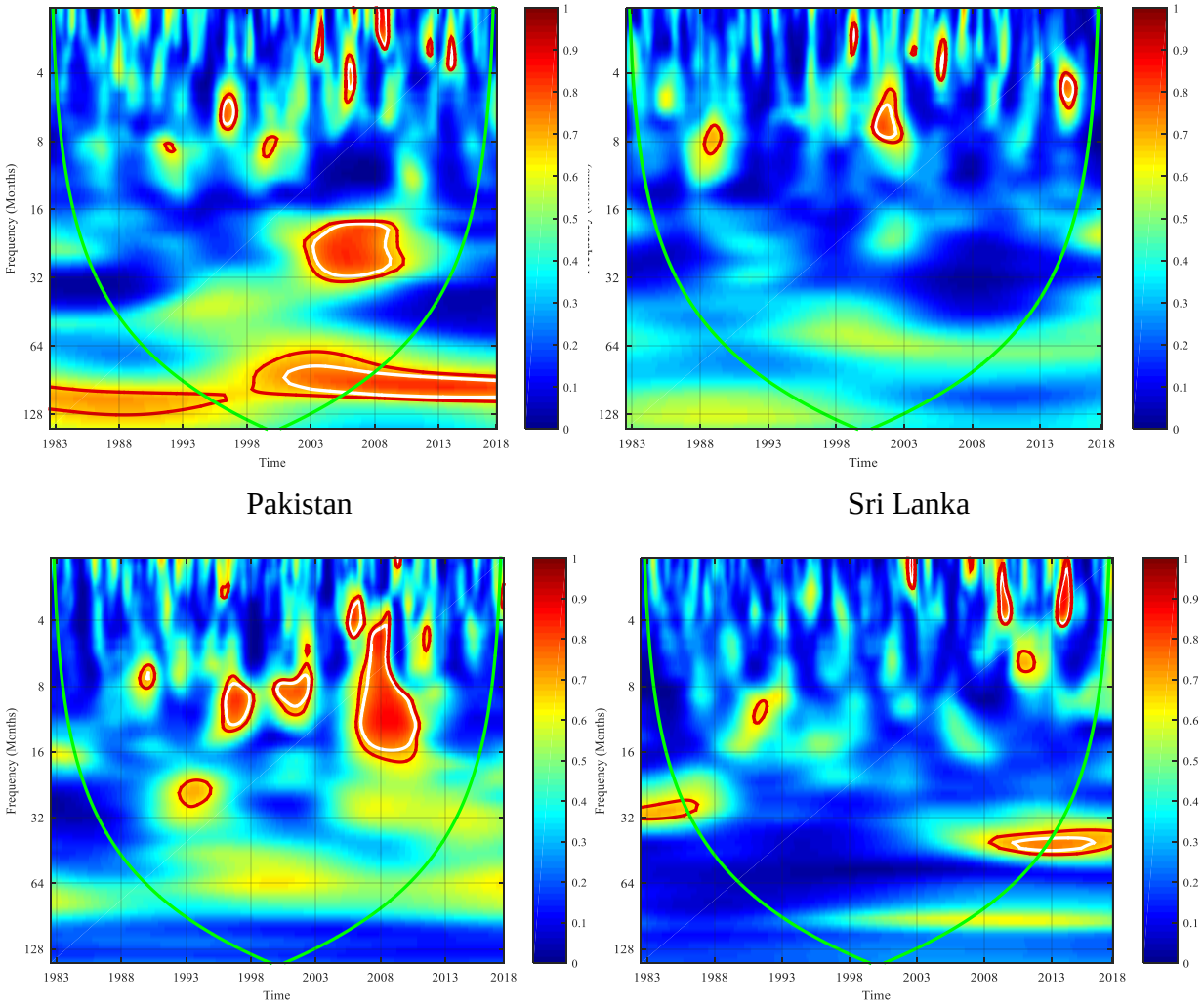


Note: Significance level at 5% is shown by thick black contour which is estimated through Monte Carlo simulations following phase randomized surrogate series.

5.4. Wavelet Causality and Correlations

Wavelet causality results are provided in Figure 5. The color code indicates strength of causality and it goes from 0 to 1. For Bangladesh strong causality between oil price and exchange rate is observed between 2003 and 2010 on 20~32 months scale and between 1998 and 2008 on 64 months onward frequency. This causal effect is little bit week in case of India and Sri Lanka and is strong in Pakistan where a strong causality holds between 2006-2011 at 4~16 months. Causality also holds at different time periods and at different frequency levels. Our results support the findings of Tiwari et al. (2013a) which also do not find causality between oil price and Indian currency at low time scales.

Figure 5. Wavelet based Causality from Oil Price to Exchange Rates
Bangladesh India



Pakistan Sri Lanka

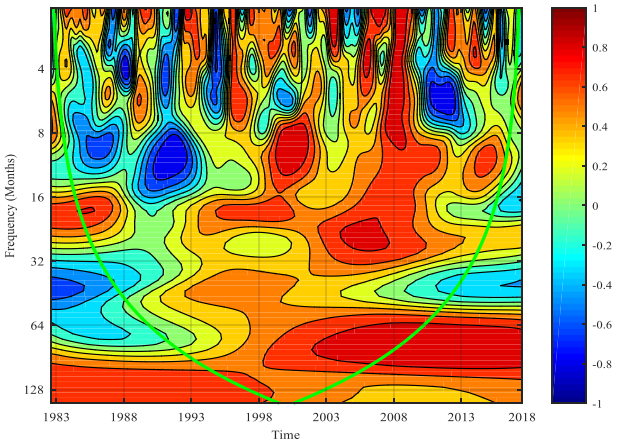
Note: Statistical significance at 5% (10%) is shown through white (red) contours.

Figure 6 reports the Rua (2013) measure of CWT correlation. It is evident from these figures that variables are positively correlated during the same period as shown in Wavelet coherency (WTC) plots given in Figure 4. These results generally support the findings of WTC. The first figure gives the correlation between oil price and exchange rate in Bangladesh. Both variables are positively correlated during 1995–2001 at 8–24 months scale (high and medium frequencies) and 2002–2010 at 0-32 months band. This positive co-movement also holds for most of the time period at low frequencies. In India, the correlation between series is observed at high to medium frequency 0-24 months scale but at different time periods. The main strong correlation is found during 2006-2010 at 5-16 months scale. For Pakistan correlation is found between 1993-2003 at 6-24 months scale and between 2006-2011 at 2-16 months scale. Correlation is also found

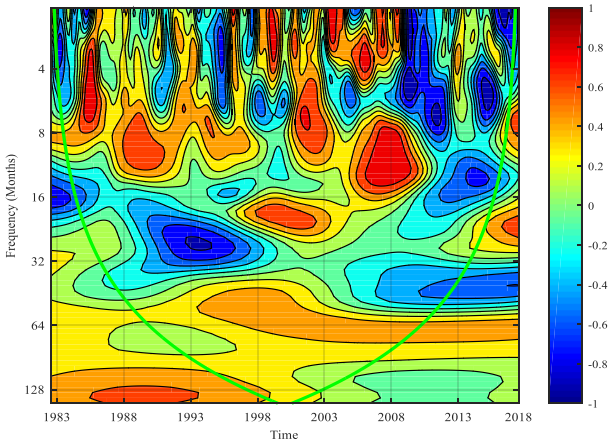
at low frequency from 1983-2004. In Sri Lanka correlation between oil price and exchange rate is found at different frequency levels and at different time periods. Correlation holds during 1989-1993 at 4-16 months frequency level and during 2004-2010 at 2-16 months scale. A very strong correlation between both series is found during 1993-2018 at 32-100 months frequency (low frequency). It indicates that oil price has affected South Asian currencies. These correlation results support the simple correlation results given in Table 2 that oil price changes are positively correlated with exchange rates in South Asia.

Figure 6. Wavelet-Based Correlations Rua (2013) Between Oil Price and Exchange Rates

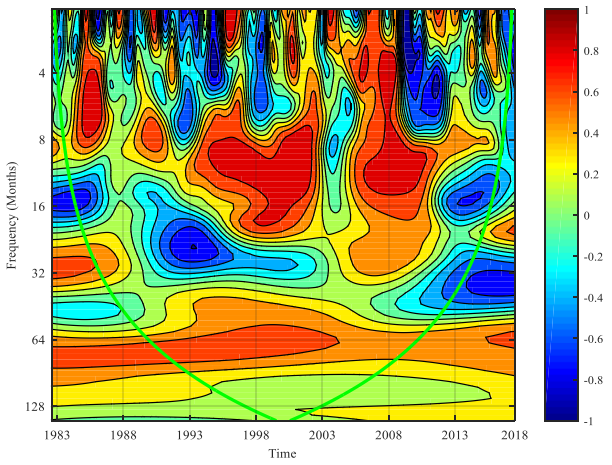
Bangladesh



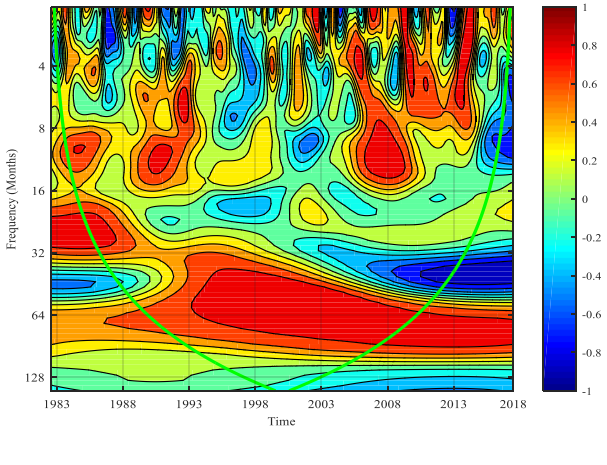
India



Pakistan



Sri Lanka



Note: The color code shows strength of correlation. Blue (read) color indicates negative (positive) correlation between variables.

5.5. Results of Linear and Nonlinear Causality Test

To validate our results of wavelet analysis and to compare our results with previous studies we have also examined causality between variables using traditional linear Granger causality test.

However, some studies in literature have pointed out that causality between oil price and exchange rate is nonlinear and that linear and nonlinear causality tests may deliver different results (Akram 2004, Wang and Wu 2012, Tiwari et al. 2013a, Benhmad 2012). Further, in the presence of structural changes in data, forecast of nonlinear models is better than linear models (Baek and Brock 1992). Therefore, the paper also examines the nonlinear causality between variables using nonlinear causality test of Diks and Panchenko (2006). Before conducting causality tests, we have first checked the stationarity of the variables by applying structural break unit root tests of Perron (1989), Zivot-Andrews (1992) and Lee and Strazicich (2003). Table 4 provides the results of unit root tests. These results reveal that all variables are non-stationary at levels and are stationary at their first differences and that all variables have structural breaks. It indicates the possibility of cointegrating relationship between oil price and exchange rates.

In the presence of structural breaks in the data, the power of the traditional cointegration tests like Johansen test falls drastically, therefore, we have applied Gregory and Hansen (1996) test to find cointegration as it takes into account the presence of structural breaks. Table 5 gives the results of Gregory-Hansen cointegration test. Estimated values of ADF and Z_t reject the null hypothesis of no cointegration in Bangladesh, India and Pakistan while the estimated values of Z_t and Z_a reject the null hypothesis of no cointegration in Sri Lanka. It indicates that oil price and exchange rates are cointegrated with each other i.e. long run relationship holds between both variables in South Asian countries.

Cointegration between variables implies that that at least one of them causes the other. Thus, it is important to examine causality between variables. Table 6 reports the results of both linear and nonlinear causality tests. Linear causality test is basically Granger (1969) causality test, while nonlinear causality test is Diks and Panchenko (2006) causality test. Both linear and nonlinear causality tests reject the null hypotheses of no causality from oil price to exchange rates, which suggests that there is linear and nonlinear causality from oil price to exchange rate in South Asia. It supports the results of Bal and Rath (2015) that there is bi-directional causality between oil price and exchange rate in India. that causality runs from oil prices to exchange rate is South Asia. Linear causality test in case of Bangladesh and non-linear causality test in case of Bangladesh and India reject the null hypothesis of no causality from exchange rate to oil price. It indicates the presence of bi-directional causality between oil prices and exchange rate in Bangladesh and India.

Table 4: Unit Root Tests with Structural Breaks

	Zivot-Andrews (1992)[a]		Lee and Strazicich (2003)[b]		Perron (1989)[c]	
	Level	First Difference	Level	First Difference	Level	First Difference
Oil Price	-4.54	-10.85*	-1.98	-10.49*	-4.50	-10.83*
Bangladesh	-4.73	-12.00*	-1.65	-10.16*	-4.72	-14.81*
India	-4.45	-10.43*	-2.10	-7.04*	-4.72	-18.41*
Pakistan	-4.34	-18.19*	-2.20	-3.86*	-4.33	-19.13*
Sri Lanka	-4.77	-15.78*	-2.98	-14.87*	-5.98	-22.41*

Note: * shows statistical significance of value at 5% level.

[a] The critical value of the Zivot-Andrews test is -4.93 at the 5% level. The number of breaks is equal to 1.

[b] The critical value of the Lee and Strazicich test is equal to -3.347 at the 5% level. The number of breaks is equal to 2.

[c] The critical value of the Perron test is -5.23 at the 5% level. The number of breaks is equal to 1.

Table 5: Gregory-Hansen Test for Cointegration

	Test Statistics				Asymptotic Critical Values		
Testing Procedure	Bangladesh	India	Pakistan	Sri Lanka	1%	5%	10%
ADF	-4.75**	-4.66**	-4.65**	-3.86	-5.13	-4.61	-4.34
Z_t	-5.03**	-5.21*	-5.98*	-5.74*	-5.13	-4.61	-4.34
Z_α	-31.57	-24.48	-23.88	-56.73*	-50.07	-40.48	-36.19

Note: Lag length is selected by using the AIC. * (**) indicates statistical significance at 1% (5%) level.

Table 6: Linear and Nonlinear Causality Tests

	H_0: Oil Price Does Not Cause Exchange Rate			
	Linear Causality Test		*Nonlinear Causality Test*	
	F-Statistics	P-Value	t-statistics	P-Value
Bangladesh	1.641	0.048**	2.570	0.005*
India	1.735	0.027**	1.915	0.027**
Pakistan	4.544	0.011**	3.256	0.000*
Sri Lanka	2.2396	0.0497**	2.417	0.007*

	H_0: Exchange Rate Does Not Cause Oil Prices			
	Linear Causality Test		*Nonlinear Causality Test*	
	F-Statistics	P-Value	t-statistics	P-Value
Bangladesh	2.030*	0.008	1.824**	0.034
India	0.943	0.532	1.869**	0.030
Pakistan	0.398	0.672	0.908	0.181
Sri Lanka	1.118	0.350	1.272	0.101

Note: * (**) indicates statistical significance at 1% (5%) level.

These results suggest that oil price affects exchange rates of oil importing countries of South Asia. Thus, governments in these countries should take appropriate steps to stabilize their exchange rates.

6. Conclusion and Policy Implications

The study examines the association between oil price and exchange rates of South Asian countries using data for the period 1983M7 to 2018M6. For empirical analysis wavelet coherence framework is used as it provides relationship among series both in time and frequency space. The results indicate that oil price and exchange rates are positively correlated. It indicates that high oil price has depreciated South Asian currencies. Being oil importing countries, this result is in line with theoretical expectations. Further the results reveal the existence of cointegration between oil price and exchange rate in all countries. The results of nonlinear causality show that there is bi-directional causality between oil price and exchange in Bangladesh and India and unidirectional causality from oil price to exchange rate in Pakistan and Sri Lanka.

These results have some important policy implications for investors and policy makers. Monetary authorities in South Asian countries should consider the role of oil price shocks in determining exchange rate dynamics. To stabilize the exchange rate after oil price shocks, monetary authorities should formulate and implement policies in such a way that minimizes the impact of oil price increase on exchange rate. Monetary authorities may concentrate on inflation target to offset exchange rate instability. Further, South Asia countries should increase domestic production of oil and look for alternative sources of energy to avoid depreciation of their currencies. High oil price can misalign the exchange rates. The flexible exchange rate system of South Asian countries can make their economies susceptible to changes in oil price shocks. As in flexible exchange rates system high oil price produces greater volatility in exchange rate compared to fixed exchange rate system. Therefore, these countries may use managed flexible exchange rate system.

Conflict of Interest

There is no any conflict of interest between the authors.

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