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Measuring co-movement of oil price and exchange rate differential in Bangladesh

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Abstract

By utilizing the wavelet analysis, investigating the co-movement of exchange rate and oil price differentials in the time-frequency space, in Bangladesh, using monthly data from 1975M7 to 2011M12, happens to be the objective of this paper. The co-movement is studied both in the time and frequency domain. A balance is being maintained in the time and frequency domain features of the data by using a wavelet-based measure of co-movement, which brings out a refinement to the previous approaches. It is being concluded that the strength of co-movement of the change in exchange rate and oil price differential varies over the time horizon in question. The policy implication from the findings is that Bangladesh Bank needs to be attentive to the shocks of oil prices while establishing a steady state of exchange rate.

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1. Introduction

The oil is considered as one of the commodities, which has a price having crucial implications for both the real economy and financial markets. Since the global oil shocks of the early 1970's, the argument regarding the linkage between oil price and exchange rate has been widespread. In recent decades, the direction of causality between these variables has been investigated in a rigorous manner. The findings of the said study done by different investigators don't appear to be unanimous. Hence, examining the relationship between these variables on a country-by-country basis becomes important from the policy analysis perspective. Although, different sort of relationship between oil prices and exchange rates have been identified, the question of the causality has not been clarified yet and still remains as one of the unsolved issues in which the researchers are interested. The price of crude oil has been a key factor in explaining the movements of foreign exchange rates, particularly those measured against the US dollar (Huang and Tseng, 2010).There are several other studies revolving around this same issue which notably include Chen and Chen (2007) for G7 countries and Lizardo and Mollick (2010) for US dollar against the major currencies. In accordance to the outcome of the said studies, increasing trend of oil prices appreciates the currency and ignites economic growth of the oil exporters relative to those of the oil importers (see Ding and Vo, 2012). However, a number of recent studies suggest that exchange rate, particularly the US dollar one, has significant influence on oil price.

The result from earlier studies takes different shapes and categories. The empirical evidences found in Zhang et al. (2008) and Krichene (2005) support unidirectional causality from the exchange rate to oil price. On the other hand, following the light of Benassy-Querea et al. (2007), Chaudhuri and Daniel (1998), and Krugman (1983, 1984); it can be ascertained that the causality runs in the reverse direction; from the oil price to the exchange rate. Finally, a bi-directional causality between the said two variables is also being found. Pursuing the works of Chen et al. (2008) and Groen and Pesenti (2010), who use exchange rates to obtain a better forecast of oil (and other commodities) prices and the works of Amano (1998) who improves the exchange rate forecast by including oil price in the model; one can be ascertained about the said claim of bi-directional relationship.

Nevertheless, wavelet analysis constitutes a very promising tool. It represents a refinement in terms of analysis, which can provide rich insights into several economic phenomena; see for example, the pioneer work of Ramsey and Zhang (1996, 1997) and Ramsey and Lampart (1998a, b). Recent studies utilizing the wavelet-based analysis extensively are used in finance and Economics[1].

To the best of our knowledge, only Benhmad (2012) and Tiwari et al. (2013) explore the oil prices-US dollar real exchange rate relationship, in a wavelet framework with application of a non-linear causality test. Benhmad (2012) discover that the linear and nonlinear causal relationships between the real oil price and the real effective U.S. Dollar exchange rate vary over frequency bands as it depends on the time scales. He reported is a strong bidirectional causal relationship for large time horizons (low frequencies). A similar result was obtained by Tiwari et al. (2013), who found bidirectional causal relationships between the oil price and the real effective exchange rate of Indian rupee at higher time scales.

However, this study is the first attempt, to the best of our knowledge, to analyse the same issue with the help of continuous wavelet. Specifically, the objective of this paper is to

[1]Kim and In (2005), which investigate the relationship between stock returns and inflation for US; Gençay et al. (2005), study the Capital Asset Pricing Model for US along with UK and Fernandez (2005), studies the same for Latin America and Asia; Gallegati et al. (2008) and Yogo (2008), dig into business cycle analysis; Rua and Nunes (2009), focus on international stock market returns for Germany, Japan, UK and US.

examine the measure of co-movement of the exchange rate and oil price differential in Bangladesh, in the time–frequency space, by resorting to continuous wavelet analysis using monthly data from $1975M_7$ to $2011M_{12}$. Co-movement in the time and frequency can be investigated applying the wavelet-based analysis. The results achieved from studying the time domain could be sensitive to the frequency of observations, while studies in the frequency domain are not always easy to translate into a time domain that corresponds to lead and lags associated with economic policies and investment decisions. In this paper, a wavelet-based measure of co-movement is being used, which constitutes a refinement to previous approaches, since it aids the time and the frequency domain features of the data. The wavelet measure of cohesion allows us to evaluate the evolvement of synchronization over time and across frequencies, simultaneously.

The paper is organized as follows; section 2 presents the wavelet-based measure of co-movement and its adoption process, section 3 depicts the empirical application of the wavelet transform at different time scale; while section 4 being the last section of this paper, revolves around the concluding tones.

2. A wavelet-based measure of synchronization

The application of the wavelet transform is that it bears local base functions that can be stretched and translated with a flexible resolution in both frequency and time. On top of it, the time resolution is intrinsically adjusted to the frequency, having a window width that narrows down while focusing on high frequencies and widens up while assessing low frequencies. Frequency bands hold an interesting aspect in wavelet analysis. Hudgins et al. (1993) and Torrence and Compo (1998) developed the approaches of the cross-wavelet power, the cross-wavelet coherency and the phase difference; which have a comparative advantage over the other methods such as time series, frequency domain and discrete wavelet approach. The comparative advantages are twofold. First, the cross-wavelet tool improves on the interactions between two time series placed at different frequencies and show how they evolve over time. Second, the cross-wavelet power of the two time series illustrates the confined covariance between the time series. Torence and Compo (1998) defines the coherency as correlation coefficient of time and frequency space and phases are defined to show the position of the pseudo-cycles of a series over time at varying frequency.

According to frequency and time spaces, the continuous wavelet transform (CWT) $\mathrm{W_t^u}(\tau)$ of a time series $x_{t,}$ at time $n_.$ and scale τ with uniform time steps, the Morlet wavelet[2] equation (1) can be rewritten in the following expression:

$$\mathrm{W_t^u}(\tau) = \sqrt{\frac{\delta t}{\tau}} \sum_{t=1}^{n} \mathrm{x_{n'}}\, \psi_\theta \left[(\mathrm{n}' - \mathrm{n}) \frac{\delta t}{\tau}\right] \qquad (1)$$

where, the wavelet power $|\mathrm{W_t^u}(\tau)|^2$ is defined as the local phase. The Cone of Influence (COI) is important to introduce a as edge effects. The Monte-Carlo simulation process is used in this paper that is explained by Torrence and Compo (1998). We computed the wavelet power spectrum[3] using the similar procedure used by Torrence and Compo (1998). The description of continuous wavelet transform (CWT), cross wavelet transform (XWT) and wavelet coherency (WTC) presentation is introduced from Grinsted et al. (2004).

[2] $\psi_\theta(\mu) = \pi^{-1/4} e^{i\omega_a \mu} e^{-\frac{1}{2}\mu^2}$, where ω_a and μ are dimensionless frequency spaces and time scales. Morlet wavelet with frequency parameter (ω_a)= 6.

[3] $D\left(\frac{|\mathrm{W_t^u}(\tau)|^2}{\sigma_u^2} < p\right) = \frac{1}{2} P_k \chi_v^2(p)$, where v is equal to 1 and 2 for real and complex wavelets respectively.

The two financial time series such as the change in real exchange rate and the change in real oil price, u_t and v_t, with the wavelet transformation $W^u$and W^v, the cross wavelet transform (XWT) is defined as $W^{uv} = W^u W^{v*}$, where W^u and W^v are the wavelet transforms of u and v, respectively, denoting complex conjugation. According to Torrence and Compo (1998), theoretical distribution of the cross wavelet power of two time series P_k^u and P_k^v with background power spectra can be defined as:

$$D\left(\frac{\left|W_t^u \tau W_t^{v*}(\tau)\right|}{\sigma_u \sigma_v} < p\right) = \frac{Z_\omega(p)}{\omega}\sqrt{P_k^u P_k^v} \tag{2}$$

The confidence level $Z_\omega(p)$ explained the square root of the product of two χ^2 distributions. Using the similar description of the XWT, the Wavelet Coherence (WTC) (Torrence and Webster, 1999) between the change in real exchange rate and the change in real oil price of two time series can be defined as:

$$\mathrm{R}_t^2(\tau_s) = \frac{\left|\varepsilon\left(\tau_s{}^{-1} \mathrm{W}_t^{uv}(\tau_s)\right)\right|^2}{\varepsilon\left|\left(\tau_s{}^{-1}\left|\mathrm{W}_t^{u}(\tau_s)\right|^2\right)\right| . \varepsilon\left|\left(\tau_s{}^{-1}\left|\mathrm{W}_t^{v}(\tau_s)\right|^2\right)\right|} \tag{3}$$

where, ε is considered as a smoothing operator (Rua and Nunes, 2009). In equation 5, the numerator is the absolute value squared of the smoothed cross-wavelet spectrum and denominator represents the smoothed wavelet power spectra (Torrence and Webster, 1999; Rua and Nunes, 2009). The value of the wavelet squared coherency $\mathrm{R}_t^2(\tau_s)$ gives a quantity between 0 and unity. This present study will focus on the Wavelet Coherency, instead of the Wavelet Cross Spectrum pursuing the application by Aguiar-Conraria and Soares (2011). In this study, we follow Torrence and Compo (1998) for identifying the COI region and phase relationship.

3. Data and empirical findings of the wavelet application

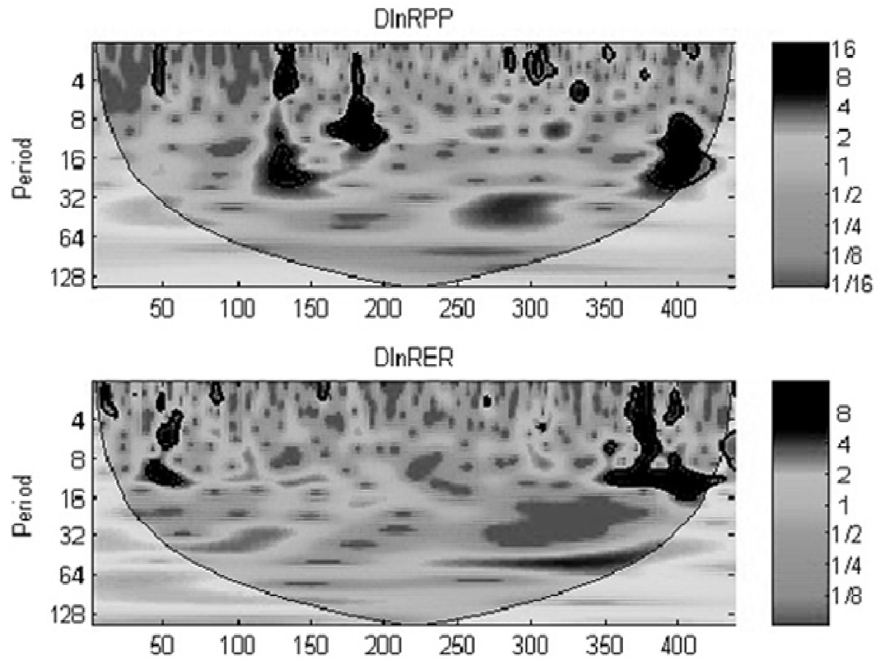
For serving the purpose of empiricism, monthly frequency data of oil prices and real exchange rate[4] is being collected over the period of $1975M_7$-$2011M_{12}$. The data span is large and sufficient for reliable and consistent results. The data about the real exchange rate were collected from international financial statistics (CD-ROM, 2012 and BBS various report). The WTI based crude oil price variable is expressed in real terms, i.e. deflated by U.S. consumer price index. The data on crude oil prices are the spot prices and are collected from Pink data set provided by the World Bank. First difference of the logarithmic transformation of the concerned variables is being used to find out the growth rates.

In this section, we report the results of the change in real exchange rate and the change in real oil price, obtained by applying the continuous wavelet power spectrum approach. The result presented in Figure-1 have common features in the wavelet high power of the change in real exchange rate and the change in real oil price that are visible around the period between July 1975 and December 2011. Information on the analysis of the result shows that the similarity between the portrayed patterns in these periods is not very much clear and for which it is hard to tell whether it is a mere coincidence or not. The cross wavelet transform

[4] $RER_t = (NER_t * p'_t)/p_t$ where NER_t is the nominal exchange rate defined in local currency units per foreign currency unit such as Taka per US$; RER_t is the real exchange rate; p'_t and p_t, respectively, are the domestic and foreign price levels (in our case price levels are measured by consumers' price index).

come up with an aid in this regard. Furthermore, the nature of data is being analyzed by utilizing cross wavelet and the result is presented in Figure-2.

Fig.1: The continuous wavelet power spectrum of both DlnRPP (top) and DlnRER (bottom)

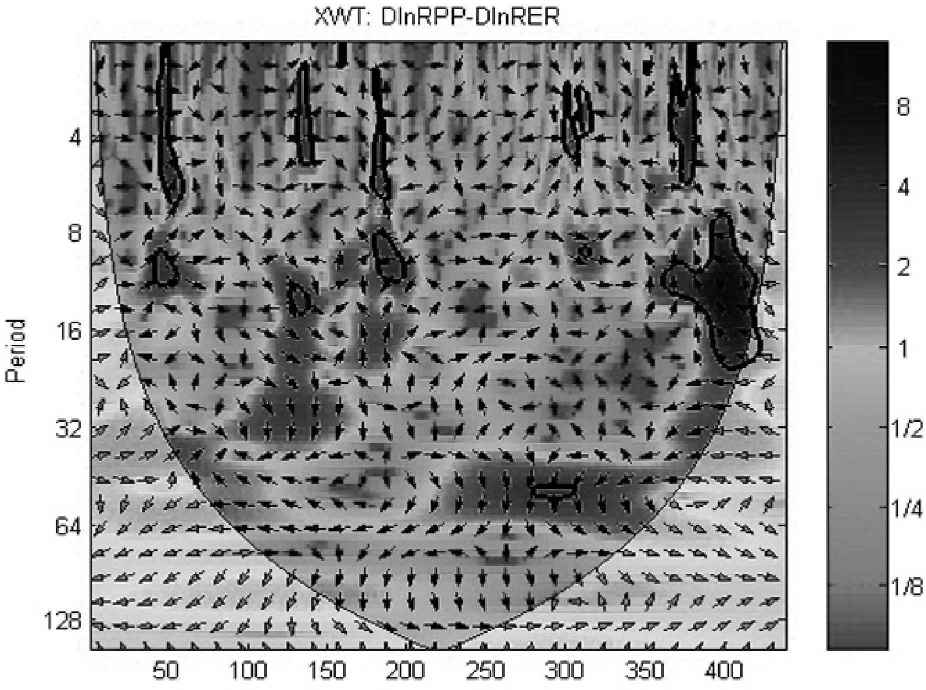


50	1979M$_{08}$
100	1983M$_{10}$
150	1987M$_{12}$
200	1992M$_{02}$
250	1996M$_{04}$
300	2000M$_{06}$
350	2004M$_{08}$
400	2008M$_{10}$

Note: The continuous wavelet power spectrum of both Real oil price change (top) series and real exchange rate change (in the bottom) series are shown here. The thick black contour describes at the 5% Monte Carlo simulations significance level applying phase series. The lighter shade black line represents the COI in this graphical presentation. The low and high powers represent the color code from white to black. X and Y axis measure the time and frequency respectively.

With regard to the co-movement between the change in real exchange rate and the change in real oil price, we find a considerable variation in the Cross wavelet power spectrum (XWT) in Figure-2. The interesting notification is that the relation at different periods (i.e., frequency bands) over the time horizon is not same. For an instance, if we consider area marked by significant region or high power region, around 1979M$_{08}$ arrows are right-up; around 1984M$_{11}$-1987M$_{12}$ arrows are right-down; around 1992M$_{02}$ there is no clear evidence; and around 2008M$_{10}$ arrows are left-up. Hence, arrows around 1979M$_{08}$ show that variables are in the phase and DlnRER is *lagging*; arrows around 1984M$_{11}$-1987M$_{12}$ illustrate that DlnRER is *leading*; arrows around 1992M$_{02}$ demonstrate no clear phase along with lead-lag relationship between variables; and arrows around 2008M$_{10}$ show that variables are out of phase and DlnRER is *leading*.

Fig. 2: Cross wavelet power spectrum of the DlnRPP and DlnRER

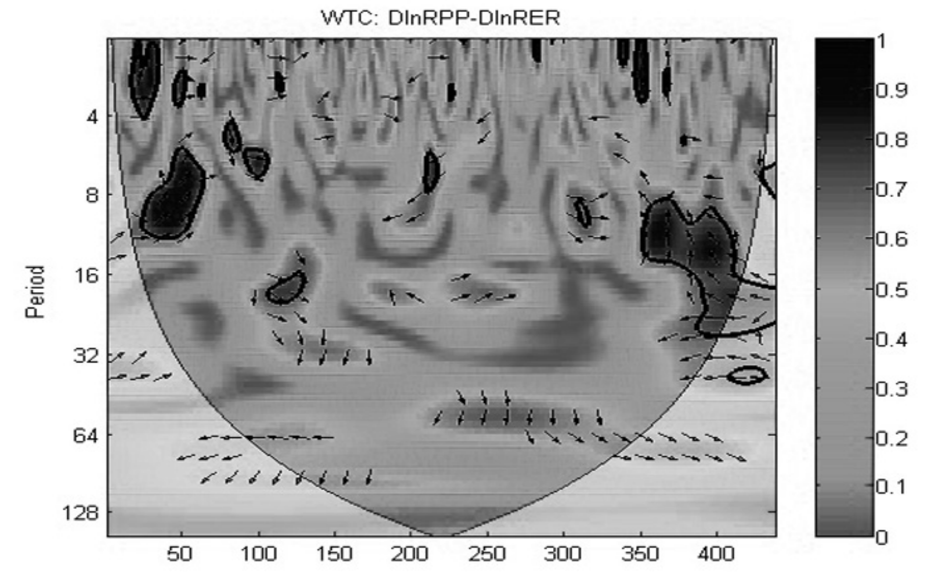


50	1979M_{08}
100	1983M_{10}
150	1987M_{12}
200	1992M_{02}
250	1996M_{04}
300	2000M_{06}
350	2004M_{08}
400	2008M_{10}

Note: The cross wavelet power spectrum of both Real oil price change series and real exchange rate change series are shown here. The thick black contour describes at the 5% Monte Carlo simulations significance level applying phase series. The lighter shade black line represents the COI in this graphical presentation. The low and high powers represent the color code from white to black. X and Y axis measure the time and frequency respectively. The sign of arrows pointing to the right, right up and right down mean that the change in real exchange rate (DlnRER) and the change in real oil price (DlnRPP) are in phase, DlnRER is lagging and DlnRER is leading, respectively. The signal arrows pointing to the left, left up and left down mean that the change in real exchange rate (DlnRER) and the change in real oil price (DlnRPP) are out of phase, DlnRER is leading and DlnRER is lagging, respectively. In phase and anti-phase show that variables will be having cyclical effect and anti-cyclical effect on each other.

Turning our attention on the cross-wavelet coherency approach, the co-movement between the change in real exchange rate and the change in real oil price, it is transparent that there remain periods and frequencies with significant relationship; yet it is not clear which variables between the two is *leading* or lagging. Therefore, from a general perspective, it is being speculated that there is a link between DlnRPP and DlnRER series, which is implied by the cross wavelet power. Moreover, it is worthy to mention that wavelet cross-spectrum (i.e., cross wavelet) describes the common power of two processes without normalization to the single wavelet power spectrum. This can produce misleading results, because one essentially multiplies the continuous wavelet transform of two time series. For example, if one of the spectra is close-by and the other exhibits strong peaks, peaks in the cross spectrum can be formed that may have nothing to do with any relation of the two series. Hence, it is being concluded that, wavelet cross spectrum is not suitable to test the significance of relationship between two time series. Therefore, to come to a concluding note, wavelet coherency (since it is able to detect a significant interrelation between two time series; to know more about refer to the equation 2) is relied upon. Nonetheless, one can still use wavelet cross-spectrum to estimate the phase spectrum. The wavelet coherency is used to identify both frequency bands and time intervals within which pairs of indices are co-varying. Finally, results of cross-wavelet coherency are presented in Figure-3.

Fig. 3: Cross-wavelet coherency of the DlnRPP and DlnRE



50	$1979M_{08}$
100	$1983M_{10}$
150	$1987M_{12}$
200	$1992M_{02}$
250	$1996M_{04}$
300	$2000M_{06}$
350	$2004M_{08}$
400	$2008M_{10}$

Note: The cross wavelet coherency of both Real oil price change series and real exchange rate change series are shown here. The thick black contour describes at the 5% Monte Carlo simulations significance level applying phase series. The lighter shade black line represents the COI in this graphical presentation. The low and high powers represent the color code from white to black. X and Y axis measure the time and frequency respectively. The sign of arrows pointing to the right, right up and right down mean that the change in real exchange rate (DlnRER) and the change in real oil price (DlnRPP) are in phase, DlnRER is lagging and DlnRER is leading respectively. The signal arrows pointing to the left, left up and left down mean that the change in real exchange rate (DlnRER) and the change in real oil price (DlnRPP) are out of phase, DlnRER is leading and DlnRER is lagging, respectively. In phase and anti-phase show that variables will be having cyclical effect and anti-cyclical effect on each other.

Found results, based on cross wavelet coherency, show that the arrows are mostly pointing upward during $1979M_{08}$ and $2004M_{08}$-$2008M_{10}$.However, during $1979M_{08}$ observation, in the 6-12 months scale, arrows are right-up, indicating that variables are in the phase and DlnRER *is lagging*; yet around $2004M_{08}$-$2008M_{10}$, in the 12-32 months scale, arrows are left-up indicating that variables are out of phase and DlnRER *is leading*. Around $1984M_{11}$ and in the 17-25 months scale, arrows are right down, indicating that DlnRER *is lagging*. Important point to be noted here is that we have restricted our results' interpretation to only significant regions. With this methodology, we therefore, unravel time and frequency dependent cyclical and anti-cyclical relationship between DlnRPP and DlnRER; which could have been impossible to detect with conventional econometric techniques.

4. Conclusion

Studying the co-movement of the oil price differential and the change in exchange rate in the time-frequency space by depending on wavelet analysis, it is being found that the strength of co-movement of the change in exchange rate and oil price differential change within the periods in question. There remains a vital policy implication pursuing the outcome, which is, Bangladesh Bank needs to be attentive to oil price shocks while aiming for a steady exchange rate. The subsidy of the government on oil prices could be a reason for which the global energy crisis is having a low impact on the fuel prices in Bangladesh.

Moreover, these results have important implications for policy makers and traders in the areas of effective risk management, monetary policy formulation in controlling inflationary pressures originating from oil or exchange rate fluctuations, Taka–dollar-pegging policy formulation for Bangladesh (being a major petrol-importing country), petrol-related assets and/or products pricing, and also in the areas of shaping fiscal policy measures in Bangladesh. We have strong evidence of coherency between oil price and real exchange rate for short and medium months cycle that corresponds to speculative trading (high frequency or noise trading i.e., for time horizons of 32 months and less). However, for the fundamentalists e.g. fund-managers and institutional investors, for business cycle of 32 months and more, less convincing evidences of coherency are found between real oil and real exchange rate returns.

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