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Relationship between Exchange Rate and Equity Prices in an Emerging Market: A Continuous Wavelet-based Analysis for Bangladesh

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Abstract

This research empirically examines the relationship between the exchange rate and stock prices by utilizing a relatively novel and non-traditional technique known as the continuous wavelet approach, which involves the continuous wavelet power spectrum, cross-wavelet transform, and cross-wavelet coherency. We employ monthly time-series data from the period 1986m09 to 2014m07 for a total of 334 monthly observations on Bangladesh. The empirical results strongly support the traditional hypothesis that the exchange rate leads (causes) stock prices compared to the alternative portfolio-based hypothesis. The implication of this finding is that policy makers need to be extra careful in managing the local exchange rate and to consider any possible effects of policy actions in the foreign exchange market on the stock market in order to avoid undesirable consequences.

Key words: exchange rate; stock prices; wavelet coherency; Bangladesh

JEL classifications: G15; C40; E32; F21; F31

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1. Introduction

There are two critical financial markets in any economy: the foreign exchange market and the equity market. It is widely documented in the literature that an equity market that functions well is of great significance for a developing country, such as Bangladesh. Such a market help a country's development by channelling domestic savings into productive investments, attracting foreign investments, and allocating scarce resources more efficiently (Bashar et. al., 2007; Kumar, 2013; and Nguyen, Islam and Ali, 2011). Similarly, the foreign exchange market also plays a very critical role in a country's development in terms of influencing its foreign competitiveness, trade volume and trade balance, foreign investments, inflation, and economic growth (Islami, 2008 and Kumar 2013).

In addition to their respective independent roles as noted above, it is also possible that the two markets are highly interconnected and may thus influence each other through different channels (Cenedese *et al.*, 2015; Islami, 2008; and Kumar, 2013). Furthermore, with increased internal and external reforms in many countries leading to greater openness and global integration of their economies with the rest of the world, it is quite possible that the foreign exchange market and the equity market have become even more interlinked. Hence, understanding the linkages between these two critical markets is of strong interest to policy makers for how to manage and regulate these markets to obtain the best possible outcome for the economy.

An important research path is to conduct an empirical study to understand and explain the behavior of these two markets and any possible linkages between them. Such a study can help policy makers understand whether and to what extent the equity market is exposed to and interlinked with the foreign exchange market and vice-versa. Thus, policy makers can adopt and follow appropriate courses of action to make these markets perform more efficiently and effectively to obtain the best possible results.

To elaborate on the above statements, the extant literature has presented that exchange rate movements tend to affect a country's international competitiveness, trade volume, trade balance, and foreign investment inflows and outflows, among

others. These in turn affect real output and inflation in a country, which may impact business performance, business cash flows (current and future), and thus stock prices. The above observation is consistent with the traditional hypothesis that a causal linkage likely flows from the foreign exchange market to the equity market (Dornbusch and Fisher, 1980). Conversely, stock price movements may also have a reverse impact on the exchange rate. With improved performance in the stock market resulting in better allocation of scarce financial resources, an economy is expected to perform better. This in turn can affect the country's foreign exchange market and its exchange rate, which is consistent with the alternative portfolio-based hypothesis (Branson, 1983; Frenkel, 1976, 1993; and Gavin, 1989).

Understanding the nature and progression of these markets and the role they might play in the development process is of even more importance for developing and emerging countries such as Bangladesh. However, as in many developing and emerging countries, the equity and foreign exchange markets in Bangladesh are both relatively underdeveloped in terms of small volume, thin trading, non-transparent transactions, corruption, poor and ineffective regulations, etc. These characteristics have made the nation's markets perform quite inefficiently (Bashar *et al.*, 2007; and Nguyen *et al.*, 2011). These markets are thus still at a nascent stage of financial development.

As more domestic and foreign investors become attracted to developing economies, it is very critical that participants have a better understanding of a country's financial sector and the relationship between the foreign exchange and stock markets. Given the above discussion, the primary objective of this paper is to empirically examine the causal relationship, if any, between these two markets for Bangladesh utilizing a novel and non-traditional wavelet-based methodology. The causal linkages to be examined include two conflicting hypotheses in the literature: whether causality goes from the exchange rate to stock prices, or there is reverse causality from stock prices to the exchange rate, or a bi-directional causality (feedback relationship) occurs between the two markets.

This paper thus empirically examines the relationship between these two critical

financial markets for Bangladesh using monthly time-series data and utilizing a somewhat novel methodology rooted in a continuous wavelet-based approach. This approach has been pioneered by Torrance and Compo (1998) and Torrance and Webster (1999) for understanding natural phenomena such as climate change. This methodology has also been used in the economics and finance literature by authors such as Aguiar-Conraria *et al.* (2008), Aguiar-Conraria and Soares (2011), Andries *et al.* (2014), Dhar *et al.* (2014), Ng and Chan (2012), Tiwari *et al.* (2013), and Tiwari *et al.* (2015).

The application of the above-mentioned empirical methodology in the economics, finance, and business literature is relatively new in the empirical finance literature, but is gaining ground. Similarly, in the area financial theory, application of the recently developed non-rationality based behavioral of economics (Kahneman, 2011) and behavioral finance (Thaler, 2015) in contrast to the conventional rationality-based theory of economics and finance as reflected in the traditional portfolio theory and/or the efficient market hypothesis.

This paper contributes to the extant literature in several ways. (1) It utilizes a relatively new continuous wavelet-based methodology to understand the relationship between the exchange rate and stock prices. (2) It fills the gap in the related literatures, as the number of empirical studies on this important relationship for the emerging equity market of Bangladesh is very rare, with only two found: Rahman and Uddin (2009a) and Rahman and Uddin (2009b). (3) Unlike the very limited five-year period of monthly data used in those two studies, this paper utilizes monthly data over a much longer time (from 1986m09 to 2014m07) with a total of 334 monthly observations. We note that Picci (2001), Atkinson *et al.* (2011), and Dufour and Renault (1998) emphasize utilizing long time series data to explain the impact of different macro-economic variables on an economy. This is quite appropriate in the context of an emerging market like Bangladesh where short time series data might not provide strong evidence on the hypothesized relationships due to poor political, socio-economic, and environmental factors, including frequent political instability in the country. Hence, we expect the long-run time series data to provide a better

understanding to explain the above-mentioned relationships for this country.

The rest of the paper is organized as follows. Section 2 gives a brief background of the Bangladesh equity market followed by a literature review and hypothesis development in Section 3. Section 4 discusses the empirical methodology used herein. Section 5 gives the empirical findings, followed by the last section's conclusions based on the findings.

2. Bangladesh Equity and Foreign Exchange Markets: A Background Discussion

Bangladesh is an emerging economy located in South Asia. Its economy has been progressing well since the mid-1990s with an average annual growth rate ranging from 4% to 6% per (World Bank, 2017). This is somewhere between the high growth rates experienced by China and India (7-10% per year) and the lower rates of 2-4% per year experienced by many mature advanced economies of North America and Western Europe (World Bank, 2017).

Along with the rapid growth of its economy, the equity market has been expanding much more rapidly (as elaborated in the next section) and attracting more domestic and foreign investors to this market, thus expanding the foreign exchange market as well. Foreign interest in its equity market increased after the country began to reform and open up its financial sector to foreign investors particularly since mid-1990. Further liberalization has occurred since the 2000s in terms of additional reforms of the stock exchanges such as greater transparency, stronger regulation, and more oversight. These reforms have increased foreign interest in the country's two equity markets.

Bangladesh has two major stock exchanges: the Dhaka Stock Exchange (DSE) and the Chittagong Stock Exchange (CSE). DSE is the largest stock exchange in the country and the focus of this paper. Formal trading in DSE began in 1956, or two years after the establishment of East Pakistan Stock Exchange Ltd. on April 28, 1954. It was renamed East Pakistan Stock Exchange Limited on June 23, 1962 and finally came to be known by its present name, Dhaka Stock Exchange (DSE) Limited, on

May 14, 1964.

In terms of regulatory structure, the capital market of Bangladesh received its first legal backing with the passage of the Securities and Exchange Ordinance in 1969. More than two decades later, the country's Securities and Exchange Commission (SEC) was established under the Securities and Exchange Act of 1993. The functions of the SEC include regulation of equity trading, protection of investors, assurance of legislative and regulatory compliances, and promotion of a fair, transparent, and efficient security market. To supervise and regulate the activities of the capital markets in Bangladesh, the SEC performs constant real-time monitoring and post-trading analysis of transactions in both DSE and CSE.

The underdeveloped and non-transparent nature of the capital market in Bangladesh provides ample opportunities for unethical and even illegal manipulations, resulting in market crashes such as that which happened in 1996 (Nguyen, Islam, & Ali, 2011). These unwarranted crashes usually cause severe financial losses to investors, particularly many small investors, and erode confidence in the markets. To control the damages caused by the 1996 crash, the Bangladesh government, with support from the Asia Development Bank (ADB), introduced the Capital Market Development Program on November 20, 1997 with several objectives: (i) strengthen market regulation and supervision, (ii) develop the stock market infrastructure, (iii) modernize stock market support facilities, (iv) increase the limited supply of securities in the market, (v) develop institutional sources of demand for securities in the market, and (vi) improve policy coordination. Since then, the market's transparency and trading environment have improved, but many more reforms and enhancements need to be achieved to make it on par at least with comparable neighboring countries in South Asia such as India (Nguyen, Islam, & Ali, 2011).

Regarding the foreign exchange market, Bangladesh has generally followed a fixed exchange rate regime since independence with occasional devaluations as deemed needed by the authorities. In this system, the Bangladesh taka was initially pegged against one single currency, the US dollar, for several years. During the mid-1980s and early 1990s, the country began to liberalize the external sector, thereby

opening the economy to more foreign trade and foreign investments. As the country diversified and got more integrated with the rest of the world, the authorities began to peg the home currency against a basket of currencies of its major trading partners such as the US dollar, British pound, Japanese yen, and European euro, among others.

Further reforms were carried out in the foreign exchange market as time progressed. For example, there were some reductions in capital controls in the capital accounts of the balance of payments since the early 2000s. In addition, partly due to pressure from international organizations, particularly the IMF, the country made a bolder move towards a relatively managed-floating type of currency exchange rate system away from the fixed exchange rate regime that prevailed until 2000. These reforms have also increased foreign interest in the country's foreign exchange market.

3. Literature Review and Hypothesis Development

The relationship between exchange rate and stock prices has been extensively examined over the years using various econometric methods, for different countries and for different time periods, but with obviously mixed results. The topic is important, because these variables are considered to be important both economically and financially for specific countries in relation to other countries in the context of an interdependent global economy.

Two important questions are generally asked in the financial and economics literature about the relationship between exchange rate and stock prices: (1) does there exist any relationship between these two variables; and if so, (2) what is the causal linkage between them? These questions are both theoretical and empirical in nature. At the theoretical level, it is argued that these two variables are strongly related with each other in the context of any given economy (Dornbusch and Fischer, 1980; Frenkel, 1993; Branson, 1983; and Gavin, 1989, among others). If relationships do exist, then the next question would concern what is the direction of the causal linkage between them; i.e., whether exchange rate changes cause stock price changes (unidirectional causality), whether there is reverse unidirectional causality of stock

prices changes causing exchange rate changes, or whether there is bidirectional causality (feedback relationship).

There are generally two competing hypotheses on whether or not exchange rate changes cause stock price changes, and vice versa. The 'traditional approach' suggests that causality runs one way (unidirectional) from exchange rate to stock prices (Dornbusch and Fischer, 1980), operating through the competitiveness of firms in the international markets. In this view, the change in exchange rates affects the value of a firm's revenues, costs (including costs of capital), and hence profits, and these changes wget reflected in changes to equity prices. For example, depreciation of the home country currency makes exporting goods more competitive in foreign markets. This is expected to lead to higher foreign demand for a firm's goods and hence more revenues and profits, thus resulting in an increase in the firm's stock prices. The opposite chain of sequence is expected to happen when the home currency appreciates, leading to a decline in stock prices.

A different approach is based on the 'portfolio balance' theory, which argues that the causality runs in the opposite direction; i.e., stock price changes trigger changes in the exchange rate, by operating through the 'capital account transactions' of the balance of payments of a country (Frenkel, 1993; Branson, 1983; Gavin, 1989). According to this view, a decrease in stock prices is accompanied by a reduction in the wealth of domestic investors, which leads to a lower demand for money and thus lower interest rates. The lower interest rates would then trigger capital outflows, and that would lead to home currency depreciation, ceteris paribus. The opposite chain of events is expected to happen when the country's equity prices rise, resulting in an appreciation of that country's exchange rate. Therefore, under the portfolio approach, stock price changes are expected to cause exchange rate changes.

Given the above competing theoretical underpinnings, it can also be argued that if a market response is simultaneous, i.e., influenced by both approaches, then a feedback relationship (bidirectional causality) is likely to emerge. In that case, the relationship between the two variables cannot be predicted, a priori. The above discussion thus makes it clear that the relationship between these two variables

remains unresolved from the theoretical perspective.

We now turn to a brief review of existing empirical literature to see whether and to what extent these two competing theories are supported or refuted by various empirical tests. As mentioned earlier, research purporting to examine the relationship between exchange rates and stock prices has been carried out in the context of different countries for different time periods with varying sample sizes. For example, Smith (1992), Solonik (1987), Aggarwala (1981), Frank and Young (1972), and Phylaktis and Ravazzolo (2000) find a significant positive relationship between the two series. By contrast, Soenen and Hennigar (1988), Ajayi and Mougoue (1996), and Ma and Kao (1990) report a significant negative relation between the two series. Granger *et al.* (2000) note that exchange rates lead stock prices in South Korea, but the reverse causality appears to be true for Hong Kong, Malaysia, the Philippines, Singapore, Thailand, and Taiwan. However, they do not find any relationship for Japan and Indonesia. Abdalla and Murinde (1997) present that stock prices Granger-cause exchange rates in the Philippines, but the opposite is true for South Korea, Pakistan, and India.

Ajayi *et al.* (1998) find unidirectional causality from stock prices to exchange rates for Canada, Germany, France, Italy, Japan, and the UK, but the results are mixed for emerging markets. These authors find bidirectional causality for Taiwan, unidirectional causality from stock prices to exchange rate for Indonesia and the Philippines, unidirectdional causality from exchange rate to stock prices for South Korea, and no significant causality arises for Hong Kong, Singapore, Thailand, and Malaysia. Leon, Narayan and Smith (2006) examine the issue of long-run co-integration between the two variables for eight Asian countries and report no long-run co-integration for these countries except for South Korea, where they show co-integration exists with weak unidirectional causality running from exchange rates to stock prices.

Empirical studies on India have produced mixed results, with most rejecting any association between stock prices and exchange rate (Rahman and Uddin, 2009; Muhammad and Rasheed, 2002; Bhattacharya and Mukherjee, 2003; Mishra, 2004;

and Venkateshwarlu and Tiwari, 2005). Abdalla and Murinde (1997) find unidirectional causality from exchange rates to stock prices, lending support for the traditional hypothesis. Several studies have examined the relationship between exchange rate and equity prices for India using time frequency analysis based on the novel continuous wavelet approach, but again with mixed results (Andries et. el., 2004; Dhar et. al., 2014; and Tiwari et. al., 2015). Overall, the causal relationship between the two series is inconclusive for India.

As for studies on Bangladesh, we can find only only two related to this topic. Rahman and Uddin (2009a) look for a long-run co-integration relationship between exchange rates and stock prices for Bangladesh, finding no such relationship, but instead present Granger causality running from stock prices to exchange rates when the exchange rates are measured by the US dollar and the Japanese yen. However, they found no Granger causality when the euro or British pound is used to measure exchange rates. Their research used only a very limited time span of monthly data from June 2003 to March 2008 for a co-integration study, and, as such, the results are not very reliable. In another study, the same authors (Rahman and Uddin, 2009b) employ monthly data from 2005 to 2008 for three South Asian countries, Bangladesh, India, and Pakistan, and show no long-run co-integration between these two series and also no Granger causality in any direction for any of these countries. Like the first study, one of this paper's major problems is that the authors use only very limited years of a monthly data time span from 2005 to 2008. It is therefore not surprising that no co-integration and no causality are found, and hence these results are not very meaningful or reliable. Another study examines the volatility of the Bangladesh equity market using the GARCH model, however, it does not specifically examine the relationship between exchange rate and equity prices (Bashar *et al.*, 2007).

It is clear from the above literature review that an extensive amount of empirical testing has been conducted over the years for different countries (or groups of countries), different time periods, and utilizing different statistical and econometric methodologies. Given these diversity of countries, time periods, and methodologies, it is not surprising to find mixed results for and against the two competing hypotheses.

Given these mixed results, the validity of the hypothesized relationship remains unresolved, which is particularly true for Bangladesh as there is a serious lack of rigorous empirical studies related to this topic for this country. Given the very limited number of studies performed, the very weak but unreliable results found for Bangladesh, and the fact that mixed results appear for other empirical studies on different countries, it is evident that further academic scrutiny is needed when examining this relationship for Bangladesh. Our paper fills some of the gaps in the related literature and offers more insights about the relationship between these variables and their causal nexus. The knowledge of the direction of causality herein sheds additional insight for Bangladeshi policymakers and can help craft appropriate policies related to these two markets in the context of a globalized world.

4. Variables, Data, and Methodology

Variables and Data

This paper uses monthly time-series data for Bangladesh for the nominal equity price index as measured by DSE (Dhaka Stock Exchange) all share index and the nominal exchange rate (ER) over the period 1986m09 to 2014m09 with a total of 334 monthly observations. The exchange rate is measured by the nominal Taka/USD exchange rate as recorded by the Bangladesh Bank, the central bank of the country. The share prices data have been collected from the Dhaka Stock Exchange and reflect the all share nominal equity price index. The data on both variables are used in level form as well as in return (logged first difference) form derived from the level series. The latter variables appear to be stationary (Figure 4 below). We note here that stationarity or non-stationarity is not an issue in wavelet analysis used by this study (Andries et. al, 2004; Dhar et. al., 2014).

Methodology

Earlier studies examining the above-mentioned relationships generally use a time-domain framework in their search for a relationship when the true relations might exist at different frequencies, which is something that can be justified on several

grounds. For example, traders in the financial market deal at different time horizons i.e., "dealing frequencies", as caused by market heterogeneity. In such cases, each market component has its own reaction time to information, because they relate to its time horizon and the characteristic dealing frequency (Dacorogna *et al.*, 2001). The link between stock returns and exchange rate returns can vary across frequencies and may even change over time. The beauty of the wavelet approach lies in its ability to decompose a time series into different time scales. This flexibility plays favorably in modelling financial market heterogeneity. The general practice among economists is to decompose a time series using discrete wavelet transform or its variant, maximal overlap discrete wavelet transform, and apply traditional econometric methods for a relationship at different frequencies. The continuous wavelet transform, by contrast, is easier to apply and can be used to carry out similar analyses without having to rely on conventional econometric techniques.

In this section we present a non-traditional and relatively new methodology based on the continuous wavelet approach for analyzing the relationship between exchange rate and equity price index for Bangladesh. Torrence and Compo (1998) develop the approach to estimate cross-wavelet power, cross-wavelet coherency, and phase difference, which can be interpreted as local variance, covariance, and time lag in the time-frequency domain, respectively. The term "phase" implies the position in the pseudo-cycle of the series as a function of frequency. Consequently, the phase difference gives us information "on the delay, or synchronization, between oscillations of the two time series" (Aguiar-Conraria *et al.*, 2008, p. 2867).

According to frequency and time spaces, the Continuous Wavelet Transform (CWT) $w_t^u(\tau)$ of a time series x_t at time n, and scale τ with uniform time steps, the Morlet wavelet[1] equation (1) can be rewritten in the following expression:

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

$$W_m^x(s) = \frac{\delta t}{\sqrt{s}} \sum_{n=0}^{N-1} x_n \cdot \psi^* \left((m-n) \frac{\delta t}{s} \right), \quad m = 1,2,\ldots, N-1 \tag{1}$$

where the wavelet power

In the two financial time series of the exchange rate (ER) and equity price index (DSE), ER_t and DSE_t, with the corresponding wavelet transformation W^u and W^v, XWT is defined as $W^{uv} = W^u W^{v*}$, where W^{v*} denotes a complex conjugate of W^v. However, according to Aguiar-Conraria and Soares (2011), WTC, instead of XWT, is preferable, since "(1) the wavelet coherency has the advantage of being normalized by the power spectrum of the two time-series, and (2) … the wavelets cross spectrum can show strong peaks even for the realization of independent processes suggesting the possibility of spurious significance tests."

According to Torrence and Compo (1998), the theoretical distribution of the cross wavelet power of two time series $\mathrm{P_k^u}$ and P_k^v with background power spectra can be defined as:

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

The confidence level $z_\omega(p)$ explains the square root of the product of two χ^2 distributions. Using a similar description of XWT, the WTC (Torrence and Webster, 1999) between the exchange rate and equity price index can be defined as:

$$R_t^2(\tau_S) = \frac{\left| \varepsilon(\tau_s^{-1} W_t^{uv}(\tau_s)) \right|^2}{\varepsilon\left| (\tau_S^{-1} W_t^{uv}(\tau_S)) \right| \cdot \varepsilon\left| (\tau_S^{-1} W_t^{uv}(\tau_S)) \right|} \tag{3}$$

Here, ε is considered to be a smoothing operator (Rua and Nunes, 2009). In equation 3, the numerator is the absolute square value of the smoothed cross-wavelet spectrum, and the denominator represents the smoothed wavelet power spectra (Torrence and Webster, 1999; Rua and Nunes, 2009). The value of the wavelet squared coherency $R_t^2(\tau_s)$ gives a quantity between 0 and unity. In other words, WTC can be defined as the ratio of the cross-spectrum to the product of the spectrum

of each series, which can be thought of as the local correlation, both in time and frequency, between two time series. Thus, wavelet coherency near one shows a high similarity between the time series, while coherency near zero shows no relationship. This present study focuses on WTC, instead of XWT, thus 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.

We define the phase difference as follows, which shows any lag or lead relationships between components:

$$\phi_{u,v} = \tan^{-1} \frac{I\{W_n^{uv}\}}{R\{W_n^{uv}\}}, \phi_{u,v} \in [-\pi, \pi] \quad (4)$$

Here, I and R are the imaginary and real parts, respectively, of the smooth power spectrum. A phase difference of zero indicates that the time series moves together (analogous to positive covariance) at the specified frequency; if $\emptyset_{u,v} \in [0, \pi/2]$, then the series move in-phase, with the time-series *v* leading *u*; if $\emptyset_{u,v} \in [-\pi/2, 0]$, then the series move in-phase, with the time-series *u* leading *v*. We have an anti-phase relation if we have a phase difference of π (or $-\pi$). If $\emptyset_{u,v} \in [\pi/2, \pi]$, then there is an anti-phase relation with *u* leading *v*; and if $\emptyset_{u,v} \in [-\pi, -\pi/2]$, then there is an anti-phase relation with *v* leading *u*.[3]

It is worth mentioning that the wavelet cross-spectrum (i.e., cross-wavelet, XWT) 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 local and the other exhibits strong peaks, then peaks in the cross-spectrum can be produced that may have nothing to do with any relation of the two series. This leads to the conclusion that the wavelet cross spectrum is not suitable to test the significance of the relationship between the two time series. Therefore, in our

[3] For a discussion on the significance level and background noise of the distribution, refer to Appendix 1.

final analysis we rely on wavelet coherency (as it is able to detect a significant interrelation between two time series). The wavelet coherency identifies both frequency bands and time intervals within which pairs of indices are co-varying. However, before presenting the results of wavelet coherency analysis, we analyze wavelet cohesion, a measure to show the co-movement of two series proposed by Rua (2010), and present results below. This measure is very similar to the correlation and ranges from +1.0 to -1.0.

Based on the above discussion, this study implements the continuous wavelet transform to examine the relationship between stock returns and exchange rate returns. Specifically, we utilize the continuous wavelet power spectrum and three cross-wavelet tools, cross-wavelet power spectrum, wavelet transform, and cross-wavelet coherency, in order to detect transient effects, which is something that traditional methods may not deliver. The tool we apply can help to unearth some economic time–frequency relations that have not been captured thus far in previous studies for Bangladesh. In other words, the continuous wavelet transform might detect causality at different time and frequency scales (domains). The methodological approach we apply should help us capture the relevance and validity of the two conflicting hypotheses and thus help detect causality relationships at different time and frequency scales.

5. Empirical Analysis and Discussion

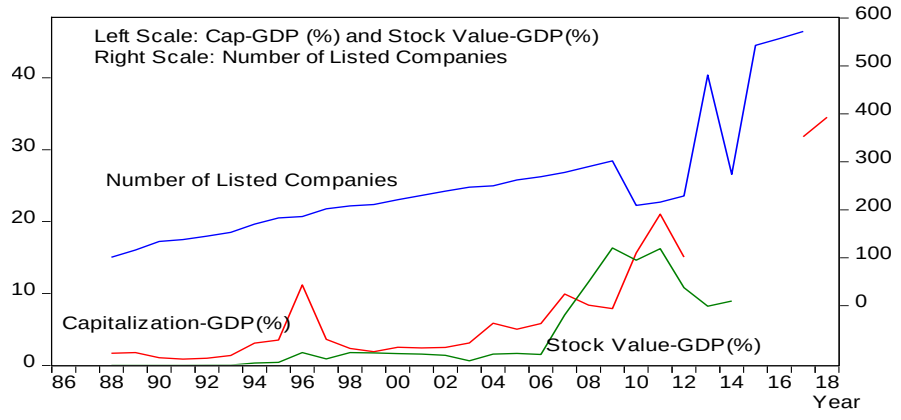
Descriptive Analysis

Prior to the independence of Bangladesh in 1971, there were 196 securities listed on DSE with a total paid-in capital of about Taka 4 billion. The daily average transaction of shares during that period was about 20,000 (Basher, Hassan, & Islam, 2007). Trading activity of DSE remained suspended, however, after the start of the war of liberation in 1971 and was restarted in 1976. When DSE restarted in 1976, there were only 9 listed companies with a paid-in capital of approximately Taka 137.52 million. By 2002-03, the number of DSE-listed companies grew to 251, having

total issued capital of Taka 35.537 billion (US$612 million) and a total market capitalization of Taka 72.167 billion (US$1,244 million). In 2008, the number of listed companies rose to 295 with a market capitalization of about US$7.067 billion (Basher, Hassan, & Islam, 2007).

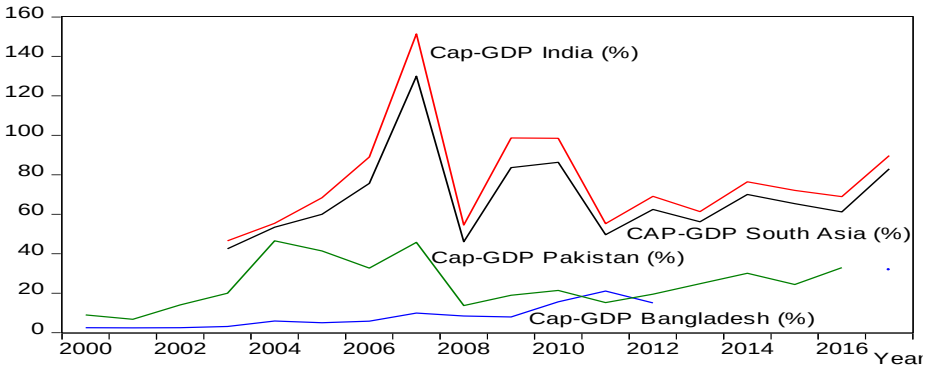
Figure 1 shows an increase in the number of listed companies in DSE from 101 companies in 1988 to the peak of 572 in 2017 (albeit with some year-to-year fluctuations). This represents a growth rate of 227% over the 30-year period from 1988 to 2017, or an annual average growth rate of 16.09%. The corresponding market capitalization as % of GDP increased from 1.68% in 1988 to a peak value of 15.06% in 2012, the last year for which data could be found. This represents a growth rate of 796% over the 25-year period and an impressive annual average growth rate of 31.84%. However, the market cap as percent of GDP for Bangladesh is still quite low compared to some other neighbouring countries such as India, Pakistan, and South Asia (as a group) as shown in Figure 2. Given the relatively low market capitalization-GDP ratio, it appears that the Bangladesh capital market needs much more development in order to catch up even with its comparable neighboring countries.

Figure 1. Bangladesh Stock Market Indicators and Trend: 1988–2017



Source: Based on Data taken from World Development Indicators, World Bank (2017)

Figure 2. Market Cap as % GDP - Bangladesh, India, Pakistan, and South Asia: 2000-2017

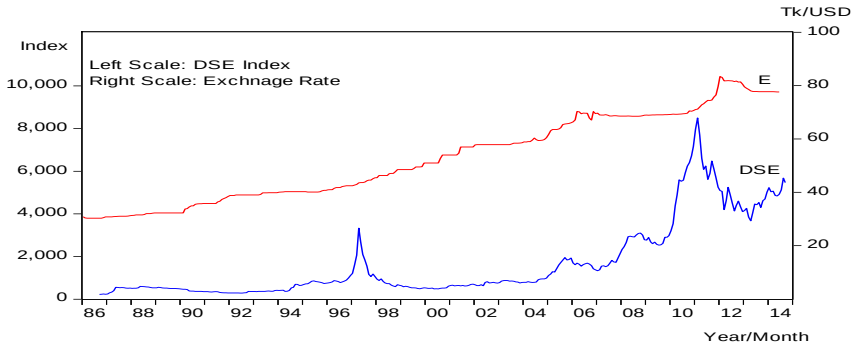


Source: Based on Data taken from World Development Indicators, World Bank (2017)

Figure 3 shows the general trend and relationship between Bangladesh Taka/USD exchange rate (ER) and the Dhaka all share price index (DSE) in their level forms for the period from 1986m09 to 2014m07. The co-movement between these two series seems to be quite strong and positive over this period, albeit with greater fluctuations of the DSE index series than the ER series. The apparent synchronized co-movement of the two series gives preliminary indications that the two series are likely co-integrated.

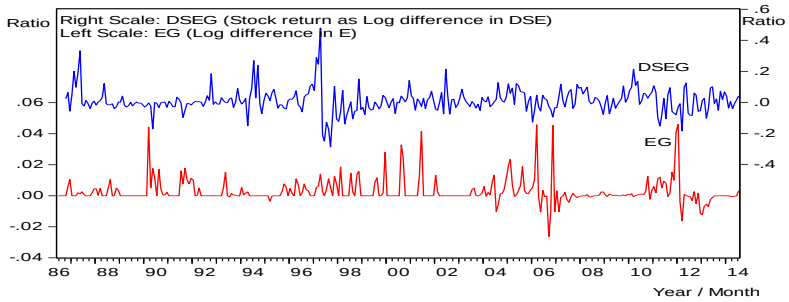
Similar patterns are observed in Figure 4, which depicts the monthly log first differences of the exchange rate return series (EG) and the log first difference of the equity return series (DSEG). Both series in the figure display significant month-to-month co-movements, but again with more fluctuations in the stock return series than the changes in the exchange rate series.

Figure 3. Time Trend of DSE and ER: Monthly 1986m09 to 2014 m09



Source: Based on Data taken from the Dhaka Stock Exchange and the Bangladesh Bank

Figure 4. Log-Differences in DSE as DSEG and ER as EG: Monthly 1986m10 to 2014 m09



Source: Based on Data taken from the Dhaka Stock Exchange and the Bangladesh Bank

Table 1 presents the descriptive statistics for DSE and ER in their log levels and also in their log first difference (rate of return) series DSEG and EG, respectively. Focusing on the stock return series (DSEG), the average monthly return is 0.0094 with a minimum of -0.0029 and maximum of 0.48. For the exchange rate return series (EG), the average monthly return is 0.0028 with a minimum of -0.03 and a maximum of 0.05. For volatility measured in terms of standard deviation, the DSEG series shows a much higher level of variability (0.08) compared to that of the EG series (0.008), thus confirming our earlier observation based on Figures 1 and 2. In terms of skewness, both the DSEG and EG series display positive skewness (long right tail), albeit with

higher skewness for the EG series. In terms of kurtosis values, both series have very high kurtosis values exceeding 3.0 (Leptokurtic distribution), again with larger kurtosis values for the EG series. Thus, the results based on skewness and kurtosis values indicate that both series deviate from the normal distribution. This observation is confirmed by the high Jarque-Bera statistic for both series, thus rejecting the null of 'normal distribution' at better than the 1% level of significance.

Table 1. Summary Statistics of DSE, ER, DSEG, and EG

	DSE	**ER**	**DSEG**	**EG**
Mean	1653.771	53.41653	0.009339	0.002826
Median	790.3056	53.35000	0.002345	0.000000
Maximum	8499.935	83.42000	0.478604	0.045995
Minimum	231.8374	30.30000	-0.287747	-0.026327
Std. Dev.	1766.628	15.72310	0.077683	0.008067
Skewness	1.620073	0.166224	0.977881	2.705911
Kurtosis	4.700593	1.700094	9.094407	14.80920
Jarque-Bera	186.3521	25.05384	570.1213	2348.368
Probability	0.000000	0.000004	0.000000	0.000000
Sum	552359.6	17841.12	3.119240	0.944021
Sum Sq. Dev.	1.04E+09	82322.85	2.009543	0.021670
Observations	334	334	334	334
Source: Author calculations				

Table 2 presents the simple correlation coefficient of DSE and ER both in their level forms and their log first difference forms. The level series show strong positive correlation of 0.7641 between ER and DSE, while the log first difference form series show a small negative correlation between EG and DSEG of -0.0393.

Table 2. Simple Correlation between DSE and ER, DSEG, and EG

	DSE	ER	DSEG	EG
DSE	1.000000			
ER	0.764094	1.000000		
DSEG	0.038412	0.000222	1.000000	
EG	-0.014595	-0.050264	-0.039327	1.000000
Source: Author calculations				

Empirical Findings and Discussion

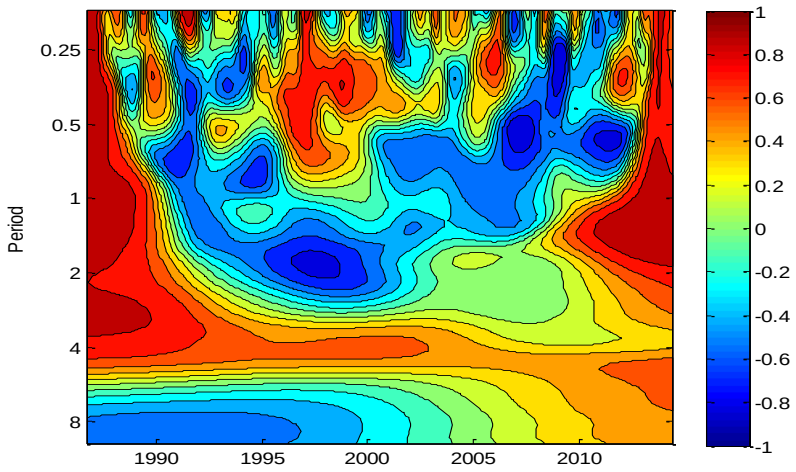
We now turn to the main empirical findings based on the wavelet methodology discussed above. First, we estimate the results of wavelet power spectrum (WPS) based on the Continuous Wavelet Transform (CWT) of both DSE and ER. Results from the WPS analysis show that both series have common features in terms of

volatility at different time scales. However, Liu *et al.* (2007) and Veleda *et al.* (2012) show evidence of bias toward low-frequency oscillations in the wavelet power spectra (WPS) and in the Cross Wavelet Transform (XWT). For example, a time series that comprises sine waves with different periods but the same amplitudes does not produce identical peaks (Liu *et al.*, 2007).[4] To address this bias issue, we prefer to use wavelets tools developed by Ng and Chan (2012), which rectify the bias in WPS (or CWT) and XWT.

Figure 5 shows Rua's (2010) measure of cohesion. As mentioned earlier, this measure of cohesion (which is similar to the concept of correlation) ranges from +1.0 to -1.0 and is shown using color codes. It is evident from this figure that before 1990 till 5 years of the time period there is high a correlation (red colour) and till 2003 during the 3-4 years' time period, the correlation is higher than 0.5, but decreases thereafter and is below 0.5 till 2011. However, since 2011, again for the time scale of 5 to 8 years it increases, and in fact for the time scale of 6 months to 3 years it is close to 0.8. A high positive correlation also appears during 1996-2000 in the 4-8 months of time scale. In contrast, evidence of a negative correlation is found during 1992-2004 in the 1-2 years of the time scale and during 2005-2011; a negative correlation arises in the time period of 1.5 years and less.

[4] These results are available upon request.

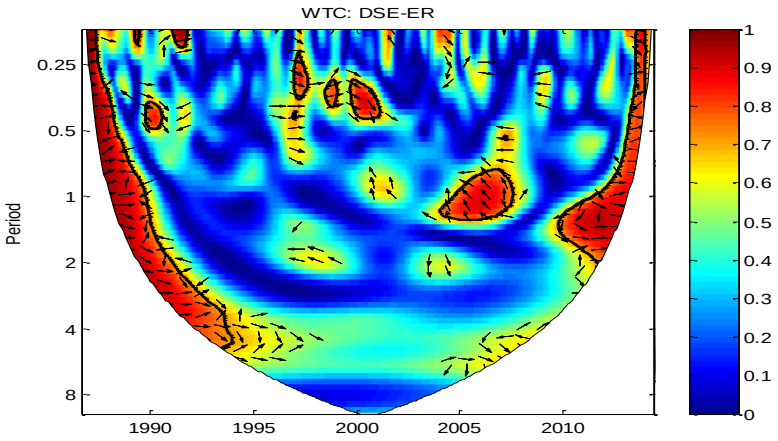
Figure 5. Rua's (2010) Measure of Cohesion



Notes: The figure shows the correlation ranges from +1 to -1 using color codes. For example, a perfect positive correlation is shown by a dark red color, and a perfect negative correlation is shown by a dark blue color.

The results of the Cross-wavelet coherency (WTC) (or squared wavelet coherency) are in Figure 6. In this figure, the thick black contour designates the 5% significance level against red noise, estimated from Monte Carlo simulations using phase-randomized surrogate series. The cone of influence, which indicates the region affected by edge effects, is also shown outside of the black line. The color code for coherency ranges from dark blue (low, close to 0) to dark red (high, close to 1). We note that "in phase" indicates that the variables have a cyclical effect on each other, while "out of phase" or "anti-phase" shows that the variables have an anti-cyclical effect on each other. The phase difference between the two series is indicated by arrows. Arrows pointing to the right indicate that the variables are "in phase", while arrows pointing to the left indicate that the variables are "out of phase." Moreover, "in phase" arrows to the right and up imply that DSE leads (causes) ER while arrows to the right and down imply ER leads (causes) DSE. When the variables are "out of phase" (arrows pointing to the left), arrows pointing to the left and up imply ER leads (causes) DSE, while arrows to the left and down imply DSE leads (causes) ER.

Figure 6. Cross-wavelet coherency (WTC) or squared wavelet coherence



Notes: The *thick black* contour designates the 5% significance level against *red* noise, estimated from Monte Carlo simulations using phase-randomized surrogate series. The cone of influence, which indicates the region affected by edge effects, is also shown outside of the *black line*. The color code for coherency ranges from *dark blue* (low, close to 0) to *dark red* (high, close to 1). The phase difference between the two series is indicated by *arrows*. *Arrows* pointing to the *right* indicate that the variables are in phase; to the *right* and up, DSE leads; to the *right* and down, ER leads. *Arrows* pointing to the *left* indicate that the variables are out of phase; to the *left* and up, ER leads; to the *left* and down, DSE leads. In phase indicates that the variables have a cyclical effect on each other, and out of phase or anti-phase shows that variables have an anti-cyclical effect on each other.

We now turn to the analysis of Figure 6, which presents the Cross Wavelet Coherency (WTC), to examine whether the variables are in phase or out of phase and whether ER or DSE is leading (causing the other variable). In the significant region of this figure, marked by a dark black line, during 1990-91, arrows are right-down in the 5 months of time scale, indicating that both variables are in phase and that the exchange rate (ER) leads (causes) stock prices (DSE). During 1996-2000, arrows are generally right-down in the 4-6 months of time scale, indicating that both variables are again in phase and hence ER leads (causes) DSE; during 2004-2007, arrows are left-up, indicating that both variables are out of phase and ER again leads and causes DSE. We do not see much evidence of right-up or left-down arrows, except a few instances. This result thus implies that DSE does not lead, i.e., DSE lags in Figure 6 in most situations of time scales and periods under study As a result, we generally conclude that ER is found to lead (cause) DSE, while DSE lags in most time scales for the context of Bangladesh. In other words, the causal linkage generally flows in

one direction (unidirectional) from ER to DSE, except in rare situations in which the opposite causality is observed.

5. Conclusion

This paper has applied the continuous wavelet-based analysis to uncover the relationship between exchange rate and stock prices with the idea that the continuous wavelet transform might detect causality at different time and frequency scales. The results obtained herein with the help of this innovative wavelet-based approach lend strong support to the traditional (Dornbusch and Fischer, 1980) hypothesis that ER leads (causes) DSE with a few exceptions and confirm the portfolio approach (Branson, 1983; Frenkel, 1993; and Gavin, 1989) where DSE leads (causes) ER, but only on rare occasions in terms of time scales. Hence, we conclude that the causal connection generally flows from ER to DSE across different time periods and frequency scales for Bangladesh, with only rare situations being the other way around. Furthermore, since the relationship is true for both in-phase and out-of-phase, the evidence supports both cyclical and anti-cyclical relationships between the two series with ER leading (causing) in both phases.

The above results clearly contradict the findings of previous studies that use traditional econometric tools and that present no long-run relationship between the two series (Rahman and Uddin, 2009a; Rahman and Uddin 2009b). As mentioned before, the results obtained from the above studies are not reliable, because they employ short time-period data for long-run co-integration analysis. Our findings herein are thus novel and offer fresh insights into the causal link between exchange rate and stock prices in Bangladesh.

This paper thus contributes to the literature and fills the research gap in at least three distinct areas. First, this is one of the very rare studies to have applied a methodology to study the relationship between stock prices and exchange rate for an emerging economy in South Asia. Second, this is the first study on Bangladesh using this methodology and utilizing much longer monthly time series data. Third, the

adoption of this novel and non-traditional methodology, in a departure from using the traditional tools of previous studies, has been instrumental in finding the exchange rate to price causality result of this study.

One implication of the observed unidirectional causality linkage flowing from foreign exchange rate to stock prices is that policy makers in Bangladesh need to focus on stabilizing the foreign exchange market to reduce fluctuations and volatility in the equity market. A second implication might be that a unidirectional causality may indicate possible violation of the well-known rationality-based investor behavior-based conventional theory of finance such as the portfolio balance theory and/or the efficient market hypothesis. In such a case, investors might be able to utilize information from exchange rate movements to predict stock price movements and can thus earn abnormal returns in the process. This may indicate that the equity market may not be efficient, at least in its weak form. In such a situation, recent developments in non-rationality-based behavioral economics (Kahneman, 2011) and behavioral finance (Thaler, 2015) could be more relevant to explain and understand such inefficient outcomes. For example, behaviors in the foreign exchange market and the equity market may show high volatility due to some non-rationality-based actions such as risk-seeking/risk-averse investing (Clark, Qiao, and Wong, 2016) or over-reaction/under-reaction investing (Fabozzi, Fung, Lam and Wong, 2013) emanating from the foreign exchange market.

In terms of public policy implication arising from this study, given that Bangladesh has begun to follow a managed floating exchange rate system since 2000 and since the exchange rate movements are found to cause stock price movements, policy makers in this nation need to be extra careful in managing the exchange rate. They need to anticipate and hence consider any possible effects of their policy actions in the foreign exchange market on the stock market to avoid any undesirable consequences in that market and thereby on the economy. As such, the results herein are expected to be benefit academics, policy-makers, think tanks, international organizations, and foreign and domestic investors alike.

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