1. Co-movement and Causality between Nominal Exchange Rates and Interest Rate Differentials in BRICS Countries: A Wavelet Analysis

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Abstract

This study uses wavelet analysis to examine the co-movement and causality between exchange rates and interest rate differentials in the BRICS countries in the period from 1996M1 to 2015M9. Empirical results indicate that co-movement and causality between interest rate differentials and exchange rates vary across frequencies and evolve over time, and they are more pronounced during the period of the recent global financial crisis in these countries. In particular, in the short run, exchange rates and interest rate differentials often move together in BRICS countries. In the long run, positive causality runs from interest rate differentials to exchange rates in South Africa and Russia, while reverse causality between these features occurs in China, and in India and Brazil, there exist bidirectional causalities between interest rate differentials and exchange rates in different sub-periods. These findings provide important implications for monetary authorities, suggesting the adoption of suitable policies to maintain exchange rate fluctuations in a well-balanced range and thereby improve the effectiveness of monetary policy. Moreover, our findings may also help investors respond appropriately to avoid the risk of changes in exchange rates and interest rates.

Keywords: interest rate differential, exchange rate, BRICS, wavelet analysis

JEL Classification: C32, F36

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1. Introduction

The main purpose of this paper is to examine the co-movement and causality between interest rate differentials and exchange rates in the BRICS countries (i.e., Brazil, Russia, India, China, and South Africa). The relationship between the two financial variables is of great importance not only to policymakers but also to practitioners. As mentioned by Holtemöller and Mallick (2016), emerging countries have consistently employed exchange rate and interest rate policies to abate inflation. Consequently, analyzing the transmission channel between exchange rates and interest rate differentials is very helpful for policymakers to control inflation and even to prevent the vicious cycle of inflation. Additionally, given that stable exchange rates help to stimulate exports and that exchange rate appreciation tends to decrease exports, exploring the causality between them can help policymakers to adopt proper interest rate policies and to avoid sharp exchange rate movements. Moreover, according to the interest rate parity condition, positive interest rate differentials can increase the attractiveness of domestic financial assets, which encourages capital inflow, and thereby limit exchange rate depreciation. Thus, adequate knowledge about the relationship between interest rate differentials and exchange rates have important implications for conducting monetary policy and allocating financial assets. In contrast, the lack of a clear understanding of the relationship between the two variables is problematic for policymakers and practitioners (Bautista, 2003; Sánchez, 2008; Andrieş *et al.*, 2017).

The relationship between exchange rates and interest rate differentials was discussed in various theoretical models of international economics. According to the Mundell-Fleming model, an increase in interest rates is necessary to stabilize exchange rate depreciation and to curb inflationary pressure and thereby helps to avoid many adverse economic consequences (Fleming, 1962; Mundell, 1963). This argument implies a negative relationship between interest rate differentials and exchange rates. The same mechanism can also be found at work in the uncovered interest parity (UIP) condition and the portfolio balance model. When equilibrating expected excess returns and holding the foreign interest rate and expected future exchange rate constant, the UIP condition suggests a negative relationship between interest rate differentials and exchange rates (Keynes, 1923; Einzig, 1931). Meanwhile, the portfolio balance model assumes that domestic and foreign assets are not imperfectly substituted and that the exchange rate is determined through balancing the demands and supplies of financial assets (Branson and Halttunen, 1979; Branson, 1983; Branson *et al.*, 1977). Consequently, a negative link between interest rate differentials and exchange rates can be inferred given the existence of a non-zero risk premium. In contrast, the flexible-price monetary model developed by Frenkel (1976) and Bilson (1978) describes a positive relationship between interest rate differentials and exchange rates. Since an exogenous increase in domestic interest rates can decrease money demand but raise consumption demand, it will further cause a rising price level and a depreciation of home currency through purchasing power parity. As a combination of the Mundell-Fleming model and the flexible-price monetary model, the sticky-price monetary model presumes that price stickiness is only an economic feature in the short term, while in the long term, prices are perfectly adjusted (see Dornbusch, 1976). Therefore, the model indicates that exchange rates and interest rate differentials are negatively related in the short run but positively related in the long run. In summary, the theoretical relationship between exchange rates and interest rate differentials is generally considered negative in the short run when product prices are sticky, and positive in the long run when they are not.

Additionally, a large number of studies have examined the relationship between interest rate differentials and exchange rates based on different countries, sample periods and selected variables. Among them, one strand of literature examines whether there is a cointegration between them. For instance, using the Engel-Granger two-stage cointegration test, Meese and Rogoff (1988) find that there is no cointegration between real interest rates and real exchange rates in the U.S., the U.K., Germany, and Japan. Employing the same technique, Edison and Pauls (1993) present that real exchange rates and real interest rates are not cointegrated in the U.K., Japan, Germany and Canada. Hoffman and MacDonald (2003) utilize Johansen's cointegration test and find support for a long-run equilibrium relationship between the output, real interest rate differentials and real exchange rates. The second strand of literature focuses on how interest rate differentials and exchange rates are related. For instance, Furman and Stiglitz (1998) argue that interest rate hikes tend to be related to exchange rate depreciation by identifying a set of episodes of temporarily high interest rates in nine emerging markets. Pattanaik and Mitra (2001) construct a VAR model and conduct an impulse response analysis. They find that a one-standard-deviation shock to the call rate appreciates the rupee in the second month. Using a vector error-correction model, Gumus (2002) suggests that higher interest rates were followed by exchange rate depreciation in the long term during the 1994 currency crisis in Turkey. Hacker *et al.* (2012) assess the relationship between exchange rates and interest rate differentials at different timescales, and present that the relationship between the two financial variables is negative at the shorter time horizons and positive in the longer horizons over a year. Andrieş *et al.* (2017) use wavelet analysis to revisit such a relationship in Romania. Their results show that the relationship between interest rate and exchange rate behaves differently between the short run versus the long run. The third strand of literature examines the causality between interest rate differentials and exchange rates. For instance, Engel and West (2005) conduct bivariate causality tests and provide significant evidence that in the U.S., there exist causality from exchange rates to interest rates. Hacker *et al.* (2014) perform causality tests using wavelet-decomposed data, and find that interest rate differentials cause exchange rates when the wavelet time scale increases. Generally speaking, no consensus has been reached, and the existing evidence cannot resolve the theoretical debate.

Notably, few studies focus on the co-movement and causality between exchange rates and interest rate differentials in the BRICS countries. Our study of the BRICS economies is justified by these countries' economic potential, which results from the size of their GDPs, geographical territories and populations. The population and land area characteristics of the BRICS countries, as well as their rate of growth and increasing proportion of international trade, make these countries important players in the global economy. Not surprisingly, both exchange rate and interest rate policies have played a vital role in the economic development and transition of the BRICS countries. Since they are often related to each other, these two kinds of policies are often used together. For example, China has made substantial achievements in economic growth by keeping its interest rate relatively low and preventing the exchange rate from appreciating too rapidly in recent decades, especially in the period before the 2008-2009 global financial crisis. During recent years, China has experienced an economic slowdown. A similar situation has also occurred in the other BRICS countries. Given this circumstance, having better knowledge about the transmission mechanism between exchange rates and interest rate differentials is of great importance for these countries to enhance the effectiveness of macroeconomic policies and to prevent their economies from slowing.

Furthermore, during the process of shifting from state-protected economic structures to market-oriented economies, the BRICS countries have conducted institutional changes and market-friendly policies, such as implementing a stimulus, more flexible exchange rates and interest rate deregulation. These steps have probably resulted in substantial time variations in the co-movement and causality between exchange rates and interest rate differentials. However, since most existing studies utilize conventional linear methods, such as correlation analysis, co-integration techniques, and Granger causality tests based on VAR or VEC models, they do not consider the time-varying issue. In addition, most of the previous literature does not consider the frequency-varying issue. In fact, given the contagious movement of interest rates across economies, when the interest rates of other economies have caught up to others, eliminating the interest rate differential, capital inflow might not occur, and hence, the upward pressure on the exchange rate will disappear. Thus, the relationship between interest rate differentials and exchange rates may behave differently between contemporaneous and inter-temporal situations.

Considering the time- and frequency-varying issue, our paper applies wavelet analysis to examine the co-movement and causality between exchange rates and interest rate differentials in the BRICS countries. Some recent studies examining the relationship between exchange rate and interest rate (differential) also employ the wavelet-based analysis, such as regression analyses (Hacker *et al*., 2012) and Granger causality tests (Hacker *et al*., 2014) using wavelet-decomposed data derived from maximal overlap discrete wavelet transform, as well as wavelet coherencies and phase differences based on continuous wavelet transform (Andrieş *et al.*, 2017). All these studies have provided strong evidence that the time-frequency domain can offer a greater advantage than either time- or frequency-domain approaches because wavelet analysis takes time, frequency, and scale into account simultaneously in a 3-D estimation. Furthermore, structural breaks do not need to be determined since wavelet analysis can identify all the dynamics of a time series (Saiti *et al.*, 2016).

This paper differs from those in the existing literature in several important ways. First, various previous studies focus on the relationship between the exchange rates and interest rate differentials in advanced economies. However, this paper concentrates on such a relationship in the BRICS countries, aiming to provide a better understanding of the transmission mechanism between exchange rates and interest rate differentials for these emerging economies. Second, wavelet analysis based on continuous wavelet transform devotes special and full attention to the time-frequency relationship between exchange rates and interest rate differentials in the BRICS countries. In this way, we can unravel the extent to which exchange rates and interest rates relate to each other, how such relationships evolve over time and whether short-run and (or) long-run relationships exist in the BRICS countries. Hacker *et al.* (2012) and Hacker *et al*. (2014) utilize the discrete wavelet transform to decompose time series data, and then conduct regression analyses or VAR-based causality tests. Obviously, this is largely different from our analysis. Andrieş *et al.* (2017) is the closest study to our analysis in terms of methodology. However, they focus on such a relationship in Romania. Third, in addition to investigating the co-movement between exchange rates and interest rate differentials for the BRICS countries, we are also interested in their causal relationships, i.e., the lead-lag relationships, which was rarely been done in existing literature. Our results support the existence of time- and frequency-varying features in the co-movement and causality between interest rate differentials and exchange rates, and show a pronounced increase in the co-movement during the recent financial crisis in the BRICS countries. In particular, in the short run, exchange rates and interest rate differentials often move together in BRICS countries. In the long run, positive causality runs from interest rate differentials to exchange rates in South Africa and Russia, while reverse causality between these features occurs in China, and in India and Brazil, there exist bidirectional causalities between interest rate differentials and exchange rates in different sub-periods. These findings provide additional and useful information for monetary authorities and investors.

The rest of the paper is organized as follows. Section 2 presents the methods used in the paper, Section 3 presents the data used, Section 4 reports the empirical results and policy implications, and Section 5 concludes.

2. Methodology: Wavelet Analysis

As an alternative to the well-known Fourier analysis, wavelet analysis estimates the spectral characteristics of a time series as a function of time (Aguiar-Conraria *et al.*, 2008) and, hence, allows the extraction of localized information in both time and frequency domains. Below, we will briefly describe wavelet transformation, wavelet coherency and phase differences.

2.1 Continuous Wavelet Transform

There are often two kinds of wavelet transforms: discrete wavelet transforms (DWT) and continuous wavelet transforms (CWT). The former is useful for noise reduction and data compression, whereas the latter is more helpful for feature extraction and data self-similarity detection (Grinsted *et al.*, 2004; Loh, 2013). In our paper, the CWT is chosen as a useful tool to decompose the concerned time series into wavelets. Concretely, the CWT $W_x(\tau,s)$ can be obtained by projecting a mother wavelet $\psi(t)$ onto the examined time series $x(t) \in L^2(\mathbb{R})$ as follows:

$$W_x(\tau,s) = \int_{-\infty}^{+\infty} x(t)\frac{1}{\sqrt{s}}\psi\left(\frac{t-\tau}{s}\right)dt \quad (1)$$

where: s is the wavelet scale that controls how the mother wavelet is stretched and τ is the location parameter that controls where the wavelet is centered. By changing the two parameters, one can construct a picture showing how the amplitudes of $x(t)$ vary across scales and how such amplitudes change over time (Torrence and Compo, 1998).

2.2 Wavelet Coherency

Wavelet coherency allows for a three-dimensional analysis that considers the time and frequency components and the strength of co-movement between series simultaneously (Loh, 2013). Consequently, wavelet coherence is used in this paper as a much better measure of co-movement between exchange rate and interest rate differentials than conventional correlation analysis and the dynamic conditional correlation method (Zhou, 2010; Liow, 2012; Loh, 2013). Following Torrence and Webster (1999), wavelet coherency between time series $x(t)$ and $y(t)$ is estimated in the sense that

$$R_{xy}^2(\tau,s) = \frac{\left|S\left(s^{-1}W_{xy}(\tau,s)\right)\right|^2}{S\left(s^{-1}\left|W_x(\tau,s)\right|^2\right)S\left(s^{-1}\left|W_y(\tau,x)\right|^2\right)} \quad (2)$$

where: $W_{xy}(\tau,s)$ denotes a cross-wavelet transform of $x(t)$ and $y(t)$. Wavelet coherency provides a value between 0 and 1 in a time-frequency window [5], and zero coherency indicates no co-movement, while the highest coherency implies the strongest co-movement. In the empirical section, the squared wavelet coherency is also clearly marked by color bars on the wavelet coherency plots, with red corresponding to a strong co-movement and blue corresponding to a weak co-movement.

2.3 Phase Difference

To be able to provide further information on positive and negative co-movement and on the lead-lag relationship between exchange rates and interest rate differentials, we also employ the phase difference. According to Bloomfield *et al.* (2004), the phase difference between $x(t)$ and $y(t)$ is defined as

$$\varphi_{xy} = \tan^{-1}\left(\frac{\Im\left\{S\left(s^{-1}W_{xy}(\tau,s)\right)\right\}}{\Re\left\{S\left(s^{-1}W_{xy}(\tau,s)\right)\right\}}\right), \text{ with } \varphi_{xy} \in [-\pi,\ \pi] \tag{3}$$

where: $\Im$ and $\Re$ are the imaginary and real parts of the smoothed cross-wavelet transform, respectively. A phase difference of zero indicates that $x(t)$ and $y(t)$ move together, while a phase difference of π ($-\pi$) implies that they move in the opposite direction. Additionally, if $\varphi_{xy} \in (0,\pi/2)$, then they positively co-move, with $x(t)$ leading $y(t)$; if $\varphi_{xy} \in (\pi/2,\pi)$, they negatively co-move, with $y(t)$ leading $x(t)$. If $\varphi_{xy} \in (-\pi,-\pi/2)$, then they negatively co-move, with $x(t)$ leading $y(t)$. If $\varphi_{xy} \in (-\pi/2,0)$, they positively co-move, with $y(t)$ leading $x(t)$. Note that the phase difference can also be indicative of causality, and is superior to the conventional causality test assuming that a single causal link holds for the whole sample period and at each frequency (Grinsted *et al.*, 2004; Tiwari *et al.*, 2013). For example, if $x(t)$ leads $y(t)$, then it suggests causality from $x(t)$ to $y(t)$ at a particular time and frequency.

3. Data

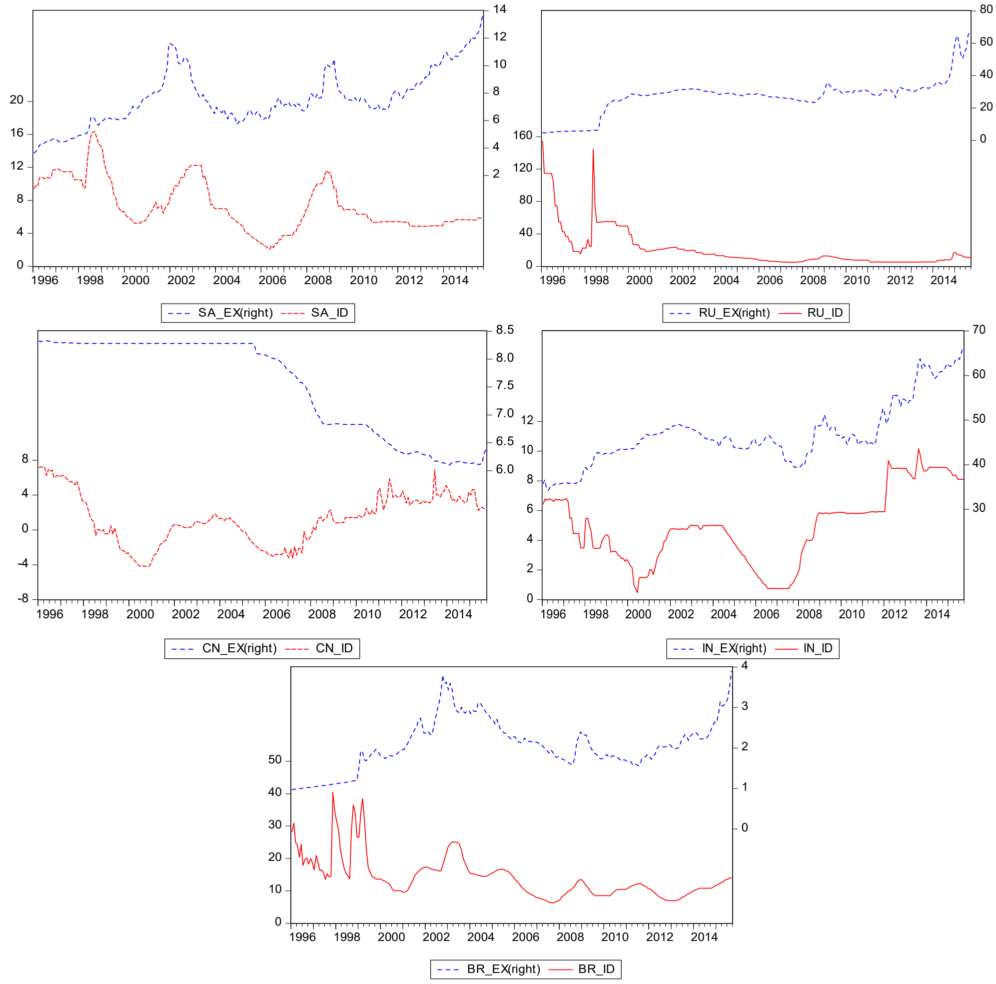
We use exchange rates (calculated as the price of the U.S. dollar in the domestic currency) and interest rate differentials (calculated as the domestic interest rate minus the U.S. federal funds interest rate) for the BRICS countries for the period from 1996M1 to 2015M9. All original datasets are obtained from the International Financial Statistics (IFS) database of the International Monetary Fund. Figure 1 shows the time-series plot of exchange rates and interest rate differentials between the BRICS countries and the U.S. It is clear that the exchange rates in South Africa, Brazil and India exhibit an obvious two-way movement pattern over the sample period, mainly because these countries employ more flexible exchange rate regimes and implement relatively fewer controls or interventions regarding exchange rate fluctuations. In contrast, both Russia and China employ a managed floating

[5] *Here, Wavelet coherency is represented by the above squared type and is smoothed by the smoothing operator S through convolution in time and frequency; see Torrence and Compo (1998) for details. Without smoothing, the squared wavelet coherence would always be 1 at any frequency and time.*

exchange rate regime. As a result, exchange rates in the two countries often move within a certain range due to frequent foreign exchange interventions by monetary authorities, and they show a significant one-way movement pattern. In terms of the relationship between exchange rates and interest rate differentials, we can clearly see that the two variables are positively correlated in the BRICS countries over some sub-periods. Despite this, however, we cannot observe any local correlations or lead-lag relationships between exchange rates and interest rate differentials. Therefore, wavelet coherency and phase difference tools are proposed in the empirical section to reveal the time- and frequency-varying relationships between these variables for the BRICS countries.

Figure 1

The Time-series Plot of Interest Rate Differentials and Exchange Rates between BRICS Countries and the U.S.



4. Empirical Results and Discussions

Figures 2-6 report the wavelet coherency and the phase difference between exchange rates and interest rate differentials for the BRICS countries.[6] Note that the correlated regions inside the COI and above the 10% significance level are not reliable indications of co-movement and causality, and the thick black lines in the wavelet coherency plot contours designate the 5% significance level estimated from Monte Carlo simulations using a phase-randomized surrogate series. As it may be clearly observed, the co-movement and causality between exchange rates and interest rate differentials show substantial time- and frequency-variations in the BRICS countries. Also, there is a pronounced increase in the co-movement during the recent global financial crisis, which suggests that the crisis has led to a significant impact on the exchange rate – interest rate differential relation across these five countries. Next, we will discuss our empirical findings along with several interesting observations country by country.

Figure 2 reports the relationship between exchange rates and interest rate differentials in South Africa. As shown, exchange rates and interest rate differentials significantly co-move across frequency bands of 0.5-1 and 1-4 years. For the 0.5-1 year frequency band (i.e., the short run), we observe positive co-movement scattered over several sub-periods—1997-1998, 2001-2003 and 2008-2010, with an average coherency of 0.65. Moreover, the phase difference around zero indicates that there are no significant lead-lag relationships between exchange rates and interest rate differentials, and these variables tend to move together in the short run. Additionally, from 2007 to 2012, we find that such co-movement appears temporarily around the 1-to-4-year frequency band (i.e., the long run), with an increased coherency of 0.85 and a phase difference within the interval $(0,\pi/2)$. This observation suggests that exchange rates and interest rate differentials strongly and positively co-move, and there is unidirectional causality from interest rate differentials to exchange rates in the long run. The intuition behind such long-term positive causality is that a higher interest rate tends to reflect a high rate of inflation, which creates pressure toward depreciation, while a lower interest rate is accompanied by a decreasing rate of inflation, which promotes exchange rate appreciation. Indeed, from 2007 to 2009, South Africa experienced relatively high inflation, leading to interest rate hikes and exchange rate depreciation. After that, with the spread of the 2008-2009 global financial crisis to South Africa, the country's inflation rate began to fall. Accordingly, the interest rate greatly lowered, and the exchange rate appreciated.

Figure 3 shows the relationship between exchange rates and interest rate differentials in Russia. We can see that the co-movement between the two variables appears across frequency bands of 0.125-0.25 and 1-4 years.

[6] *Note that, since wavelet analysis can be performed even if the underlying series are non-stationary or are locally stationary (Roueff and Sachs, 2011), we do not conduct any unit root test in this paper.*

Figure 2

The Wavelet **Coherency** (A.1) and Phase Difference (A.2, A.3, and A4) between Exchange Rates and Interest Rate Differentials in Brazil

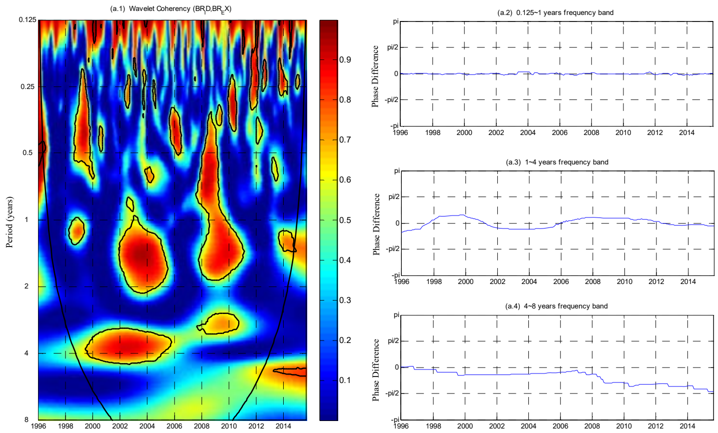
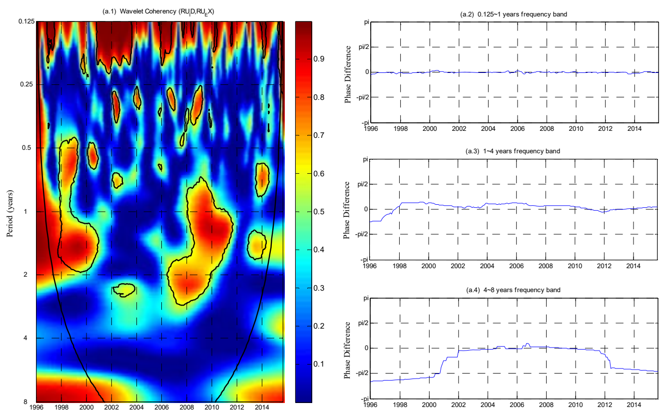


Figure 3

The Wavelet Coherency (A.1) **and** Phase Difference (A.2, A.3 and A4) between Exchange Rates and Interest Rate Differentials in Russia



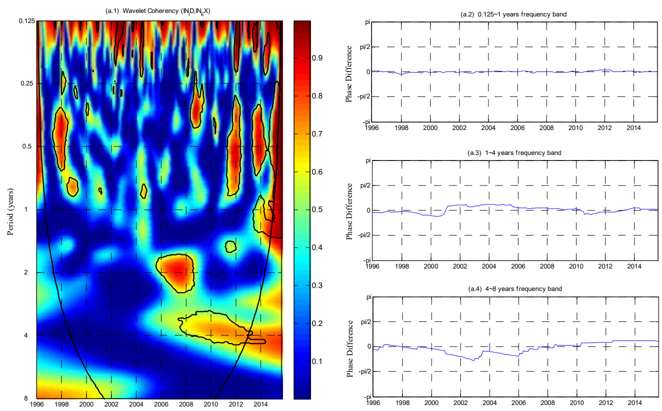
Concretely, for the 0.125-to-0.25-year frequency band, co-movement is more significant over the 2001-2003 period, with an average coherency of approximately one and a phase difference around zero, suggesting that co-movement is strong and positive and that there seems to be no significant causal linkage between these variables in the short run for Russia. At the 1-to-4-year frequency band, strong and positive co-movement can be observed in the 1998-2001 and 2007-2011 periods, and a phase difference within the interval $(0, \pi/2)$

suggests that there exists long-run causality running from interest rate differentials to exchange rates. During 1998-2001, Russia experienced a serious financial crisis due to substantial capital outflows, and as a result, investor confidence eroded. Though the central bank raised the interest rate substantially, the inflation rate remained at a high level, and the Russian ruble continued to depreciate. During 2007-2011, Russia experienced an economic situation similar to that of South Africa, hence contributing to positive causality running from interest rate differentials to exchange rates in Russia.

Figure 4 displays the relationship between exchange rates and interest rate differentials in India. Quite different from the findings for South Africa and Russia, in India, the co-movement between the two variables decreases significantly. In addition to the scattered co-movement across the 0.25-to-1-year frequency band, relatively stable co-movement occurs at the 1-to-4-year frequency band and during the 2006-2013 period. Moreover, the average coherency is approximately 0.6, meaning that the degree of co-movement in India is weaker than that in Brazil and Russia.

Figure 4

The Wavelet Coherency (A.1) and Phase Difference (A.2, A.3, A4, and A5) between Exchange Rates and Interest Rate Differentials in India



Additionally, the phase difference of $(-\pi/2, \pi/2)$ indicates that exchange rates and interest rate differentials positively co-move over this period on one hand, and on the other, there is causality from interest rate differentials to exchange rates before 2010, while after that, reverse causality can be clearly observed. As mentioned above, positive causality from interest rate differentials to exchange rates during the 2006-2010 sub-period is not surprising. The rising inflation in this sub-period has also contributed a rising interest rate and depreciation in the exchange rate. This finding confirms that inflation also plays an important role in shaping the relationship between exchange rates and interest rate differentials in India. For the following 2011-2013 sub-period, the Indian rupee continued to depreciate. In order to prevent greater depreciation because of accelerating capital outflows, India has continued its high interest rate policy to assimilate the excessive volatility of exchange rates in the foreign exchange market. Consequently, the interest rate differential relative to the US has remained at a high level during the sub-period. This finding implies that although a floating exchange rate regime was employed, a high interest rate policy might still be used in India whenever there is pressure toward depreciation.

Figure 5 presents the relationship between exchange rates and interest rate differentials in China. We can see that at the 1-to-4-year frequency band, there exists statistically significant co-movement between the two variables over the period from 2005 to 2011. Meanwhile, the phase difference is located within the interval $(-\pi/2,0)$ and coherency is approximately 0.7, indicating that exchange rates and interest rate differentials in China are positively related, and exchange rates have a relatively stable causal effect on interest rate differentials during this period. This finding fits well the situation of China. Indeed, since the reform of the exchange rate regime in 2005, the renminbi (RMB) has experienced accelerated appreciation in both nominal and real terms, creating a persistent expectation of appreciation and stimulating a surge of capital inflows, thus exerting pressure on the RMB's appreciation. Under this circumstance, China's interest rate was greatly reduced to alleviate the appreciation pressure. This finding proves that China's interest rate policy tends to promote the stability of exchange rates. Although this policy helps to expand exports, it may weaken the independence of monetary policy and thereby harm internal balance. Meantime, the one-way exchange rate movement is also likely to increase arbitrage activities, and may lead to substantial capital outflows once the expected change in the exchange rates cannot be discontinuous. Consequently, China can adopt a more flexible exchange rate regime to enhance the effectiveness of its monetary policy.

Figure 5

The Wavelet Coherency (A.1) and **Phase** Difference (A.2, A.3, A4, and A5) between Exchange Rates and Interest Rate Differentials in China

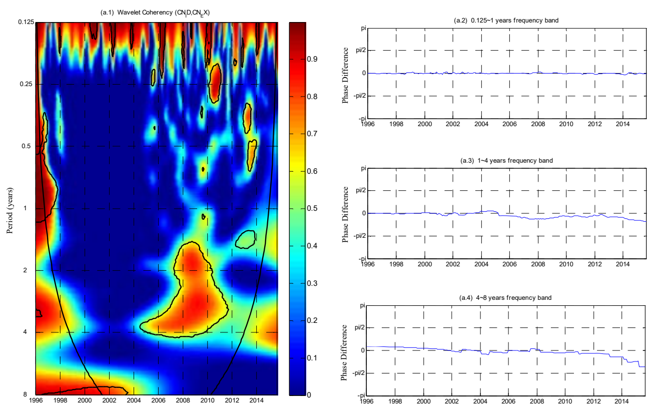
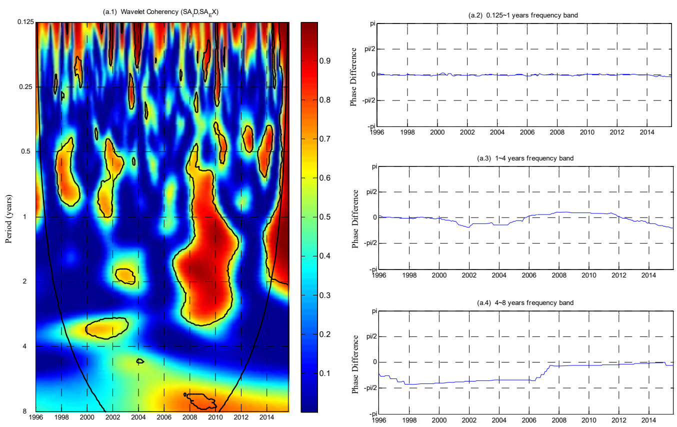


Figure 6 shows the relationship between exchange rates and interest rate differentials for Brazil. At the 0.25-to-1-year frequency band, we observe that the co-movement between the two variables occurs mainly in two periods – 1998-2000 and 2008-2009 – with the phase difference around zero, suggesting not only that these variables positively co-move but also that there is no significant causal effect between them. At the 1-to-4-year frequency band, the co-movement between the two variables occurs in the other two periods, 2002-2005 and 2008-2011, with the phase difference within the interval $(-\pi/2,\pi/2)$ indicating that they positively co-move. Additionally, the lead-lag relationship between interest rate differentials and exchange rates suffers from structural changes. Owing to the "Lula effect"[7], the exchange rate of the Brazilian real (BRL) experienced significant depreciation in 2002-2003, subsequently leading to a hike in the domestic interest rate. Thereafter, with the BRL appreciating, Brazil's interest rate decreased greatly. Therefore, we observe causality from exchange rates to interest rate differentials during 2002-2005, while in the 2008-2011 period, we find that interest rate differentials Granger-cause exchange rates. Indeed, during the global financial crisis, relatively high interest rates did not lead to an appreciation of the BRL mainly because both the rising inflation and capital outflow brought depreciation pressure. After that, due to substantial capital inflows and the economic recovery, the BRL began to appreciate even though the interest rate differential relative to the U.S narrowed.

Figure 6

The Wavelet Coherency (A.1) and Phase Difference (A.2, A.3, A4, and A5) between Exchange Rates and Interest Rate Differentials in South Africa



5. Conclusions and Policy Implications

This paper explores the co-movement and causality between exchange rates and interest rate differentials in the BRICS countries, with wavelet decomposition utilized to consider these relationships at different frequencies and over different time periods. Our results show that co-movement between interest rate differentials and exchange rate varies across frequencies and evolves over time, and it was more pronounced during the period of the recent financial crisis. In particular, in the short run, exchange rates and interest rate differentials often move together in BRICS countries. In the long run, we find that there is a positive causality running from interest rate differentials to exchange rates in South Africa and Russia and reverse causality in China. For India and Brazil, there exist bidirectional

[7] *Ferreira and Sakurai (2013) note that: "A final shock the consequences of which were only fully felt under the next government came with the sharp depreciation of the domestic currency in 2002. This significant hike in the exchange rate was observed after the polls indicated an increased likelihood of the left-wing candidate's victory (Lula)."*

causality between interest rate differentials and exchange rates in different sub-periods. These findings greatly conflict with the previous literature, which claims that a stable relationship holds over the whole sample period and across all frequencies, but accord with Hacker *et al.* (2012) and Hacker *et al.* (2014), who take time variations and frequency variations into account.

Our findings provide important implications for monetary authorities and investors. First, our findings confirm that inflation has a high impact on the relationship between exchange rates and interest rate differentials in four BRICS countries (i.e., South Africa, Russia, Brazil and India), which often leads to positive causality from interest rate differentials to exchange rates. In other words, exchange rates and interest rate policies are useful for policymakers to control inflation in these four countries. Second, our findings also prove that China's interest rate policy is often used to promote the stability of exchange rates, which may weaken the independence of monetary policy and hence harm the internal balance. Consequently, if China seeks to enhance the effectiveness of its monetary policy, then a more flexible exchange rate regime should be adopted. Finally, investors can use the information on the relationship between interest rate differentials and exchange rates and thus take corresponding measures to avoid the risk of changes in exchange rates and in interest rates.

Our analysis is studied with bivariate variables. In fact, the co-movement and causality between exchange rates and interest rate differentials may be affected by other variables. In future research, we can further study such relationships by including the other macroeconomic factors to enhance the persuasiveness of the paper.

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