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Abstract

To understand whether regional proximity leads to exchange rate connectedness, we explore dynamic co-movement of currencies from two important regions namely the South Asian Association for Regional Cooperation and Association of Southeast Asian Nations by using Continuous Wavelet Transformation approach. Our results reveal very little co-movement between member currencies of both regions and imply that regional proximity does not necessarily translate into exchange rate connectedness. The results remain robust to alternate specifications. Our findings carry important implications for academia and policymakers.

Keywords: Exchange Rates; Currency connectedness; SAARC; ASEAN; Wavelet

Classification codes: F31

1 Introduction:

Global markets are interconnected due to preferential and regional trade relationships, cross-border and cross-pillar investment and banking activities, market openness, and political, social and locational contiguity. Foreign currencies are the most versatile 'balancers' in this connected world, as the trading imbalances are reflected in currency reserves, the balance of payment, and monetary policies (Sehgal et al., 2017a). The influence of and the need for interconnectedness have been so significant that since the global financial crisis of 2007-08, large countries that often consider themselves equally trade partners and competitors otherwise, such as the United States, China, European Union, Germany, and Japan, have revised their trade policies and partnerships. The high volume of capital flows to and from emerging Asian markets is often contagious, affecting trade balances, and creating monetary shocks. Connectedness, interconnectedness, spillover, and risk contagion are often used to measure connected shocks that are accumulated asymmetric upsets in the realized impact of value, say from the global currency market (Yoon et al., 2022).

Why it is important to explore exchange rate spillover? In effect, currency connectedness strongly influences market efficiency and investors' portfolio performance (Meng & Huang, 2019). Due to extreme connectivity, during higher uncertainty, systemic risk is the highest among several currency pairs, which should be reconsidered by investors during their diversification exercise. Currency spillover might be contagious and purely fundamental (Dewandaru et al., 2017). Recent research indicates that regional currency market connectedness is a growing concern among global superpowers, particularly due to the growth of 'south-south' trade partnerships among China and other South Asian and Southeast Asian countries (B. H. Kim et al., 2013; Kinkyo, 2021; Lee et al., 2018; Meng & Huang, 2019; Mishra et al., 2020; Pandey & Sehgal, 2018; Sehgal et al., 2017a).

In view of growing scholarly preponderance of Asian currency connectedness, this study adds to the literature on foreign currency dynamics in two important regions namely South Asian Association for Regional Cooperation (SAARC) and Association of Southeast Asian Nations (ASEAN) regions by investigating the influence of regional proximity on currency spillover. To examine the influence of regional proximity of the SAARC countries on exchange rate spillover, this study selected five SAARC countries, namely Bangladesh, India, Maldives, Pakistan, Sri Lanka. We compare our findings with currency spillover from the four ASEAN countries that include Indonesia, Malaysia, Philippines and Thailand. South Asian countries are plagued by low trade connectivity and poor currency market linkages (Sehgal et al., 2017). Conversely, strong linkage, openness and uncertainty are the keywords that explain currency market co-movement in East Asian market. These two regions are examples of heterogeneity among trade relations and cooperation among otherwise neighbouring countries. Hence, these regions are suitable choice to investigate if the exchange rates of neighbouring countries exhibit interconnectedness or not.

Following several existing studies (Andrieş et al., 2016; Meng & Huang, 2019; Qureshi & Aftab, 2020), we have employed the Wavelet methodologies to examine the spillover impact. Our findings carry important insights: The results of the Wavelet spectrum on SAARC as well as ASEAN exhibit strong time-varying cycles of short- and long-term volatility. These effects are

presented by several events including excessive capital inflows and outflows in the aftermath of the global financial crisis, and low frequency volatility due to oil market crisis and geopolitical tensions. Wavelet coherence tests show that the pairs of SAARC currencies did not reveal any significant co-movement. Our findings are similar to an earlier set of findings by Sehgal et al., (2017). Similar results are found for ASEAN countries. There are rare volatility and co-movement among currencies. Malaysian Ringgit is leading the co-movement in most cases. These results on the ASEAN countries are supported by Shahrier (2022). We control the co-movement of member currencies with global factors and our results remain are robust to these alternatives methods and specifications.

We make important contributions to the existing literature: First, Studies on connectedness and co-movement have superior presence in the equity and bond markets (Abdul-Rahim et al., 2022; Baruník et al., 2016). There are three branches of research on currency market connectedness. First, a growing list of research investigates intra-market connectivity, spillover and systematic risk with the currency market (McMillan & Speight, 2010; Mittal et al., 2019; Pandey & Sehgal, 2018; Qureshi & Aftab, 2020; T. Wen & Wang, 2020). Second, currency market co-movement with other financial and commodity markets are discussed widely (Caporin et al., 2021; Kočenda & Moravcová, 2019; Meng & Huang, 2019; Qureshi & Aftab, 2020; Tamakoshi & Hamori, 2014). Third, researchers also show interest towards volatility contagion and inter-market connectivity on a global scale (Kinkyo, 2021; Qarni & Gulzar, 2021; Shah et al., 2021; Shang & Hamori, 2021; Tiwari et al., 2018; T. Wen & Wang, 2020). Nevertheless, to the best of our knowledge, no study has endeavoured to assess how regional proximity might affect currency connectedness.

Second, although existing studies (Sehgal et al 2017a; Qureshi and Aftab 2020; Shahrier 2021) have explored the connectedness pattern for both the reasons, our study is unique in different respects. Our study differs from Qureshi and Aftab (2020) in respect of data range and context. While Qureshi and Aftab (2020) investigated ASEAN5 countries, we examined the SAARC5 countries, and we had an extended data set. On the data range, we have also extended data on Sehgal et al. (2017). In a similar study on ASEAN, Shahrier (2022) considered only the COVID period data. We have considered the data range from August 2008 until June 2022 that cover a number of important events including the post global financial crisis era and the on-going COVID-19 pandemic period.

The reminder of the paper is structured as follows. Bibliometric analysis of the literature is presented in chapter 2. Chapter 3 discussed empirical setting, data and methodology. Chapter 4 summarizes findings. Chapter 5 concludes the study.

2 Bibliometric Review

We conduct the visualization network analysis based on the bibliometric approach (Khan et al., 2020, 2022) to highlight the existing conceptual and intellectual structure of the literature on the dynamics of interconnectedness and volatility spillover within exchange rate and currency markets and subsequently how it influences various financial markets. To this end, we extract the literature

data using the appropriate keywords such as "currency" and “exchange rate" coupled with "Systemic risk", "connectedness", "Interconnectedness", "Spillover", "Contagion", "volatility" and searched them in the title. We, then, run the visualization of keyword/trend (figures 1 and 2) and bibliographic coupling analysis (figure 3) on the extracted literature data.

The keyword analysis in figure 1 shows that “exchange rate”, “models”, “foreign-trade” “market” “stock-market volatility”, “transmission”, “linkages” and “crude oil” are the most repeated keywords within the existing literature. Overall, the literature is discussing about exchange rate volatility interventions (Bayoumi and Eichengreen, 1998; Rose, 1996; Sahay and Ramachandran, 2022), its pattern during turmoil times (Coudert et al., 2011; Feng et al., 2021), the impact of exchange rate volatility on foreign trade (Bahmani-Oskooee and Gelan, 2018; Tenreyro, 2007) and oil prices (Wen et al., 2018; Zhang et al., 2008), economic uncertainty impact on exchange rate volatility (Krol, 2014; Sohag et al., 2022) and lastly, the model to price the currency options (Heston, 1993; Kim et al., 2019; Jeon and Kim, 2022).

[Figure 1]

Similarly, figure 2 reveals that earlier literature (before 2016) assesses the models to estimate exchange rate volatility, its impact on foreign trade, capital flow, and exchange rate pass-through in currency markets both in developed and emerging markets. However, the recent literature (after 2016) highlights the exchange rate spillover during crisis times along with the asymmetric effect of exchange rate volatility on various financial markets.

[Figure 2]

To further highlight the dimensions and streams of the literature, we also perform a bibliographic coupling analysis to identify the streams and then critically discuss the state-of-the-art literature on exchange rate volatility.

The stability in exchange rates fosters the growth of the regional economies and promotes international trade and investment (Jiang et al., 2022b), however, macroeconomics shocks drive the fluctuations in the foreign exchange markets. The correlation among foreign exchange markets varies based on the increasing economic dependence and monetary integration that involves exchange rate volatility and price stability (Portugal Duarte and da Silva, 2022). For example, lower exchange rate risk will increase the trade among the economies, thereby, increasing the co-movement among the currencies. Similarly, the exchange rate spillover is also driven by the nature of the economic structure, geographical immediacy, and informational asymmetries.

To this end, the red stream mainly focused on the exchange rate volatility and its intervention (Bayoumi & Eichengreen, 1998; Fanelli & Straub, 2021; Keefe & Shadmani, 2018; Rose, 1996a; Sahay & Ramachandran, 2022a), dynamics of exchange rate volatility during crisis times (Anwer et al., 2022b; Ben Omrane and Savaşer, 2017; Coudert et al., 2011; Feng et al., 2021; Fratzscher, 2003).

The seminal work of Mundell (1961) on the Optimum Currency Areas (OCA) hypothesizes that specific regions benefit more to form a single currency than from using their own currency. Understanding the implication of OCA, Bayoumi and Eichengreen (1998) find that jurisdictions with variable exchange rates are vulnerable to asymmetric shocks which result in increased pressure on the exchange market, thus, interventions are necessary to reduce this variability in the exchange market. The interventions in the foreign exchange market are deemed to reduce the volatility in the market (Rose, 1996b). Similarly, Keefe and Shadmani (2018) investigate the central bank behavior of emerging economies to mitigate the fluctuations in the foreign exchange market. They find strong evidence of central bank interventions to reduce sharp depreciation or appreciation. While (Sahay and Ramachandran, 2022) considered these interventions counterproductive and create more variability than stability in the market.

Another strand of literature within this stream highlights the response of exchange rate volatility to ongoing health crises as well as global financial crises. For example, Coudert et al. (2011) argue that exchange rate spillover is more pronounced and channelized from developed countries to emerging countries during crisis times. Using the data of 21 emerging economies from January 1994 to September 2009, they document that spillover among currencies is proportionally higher during global financial crises with contagion effect from one emerging country to a neighboring one. The spillover among currencies also depends on the level of financial interconnectedness which might forecast the transmission of future financial crises (Fratzscher, 2003). Similarly, volatility in the exchange rates also increases during Covid times, however, the government fiscal and aid measures restrain the exchange rate volatility (Anwer et al., 2022; Feng et al., 2021).

Green stream highlights the impact of exchange rate volatility on cross-border trade (Asteriou et al., 2016; Bahmani-Oskooee and Aftab, 2017; Bahmani-Oskooee and Gelan, 2018; Sharma and Pal, 2018; Tenreyro, 2007) and how it affects the growth of export (Boug and Fagereng, 2010; Kabir Hassan and Tufte, 1998). The exchange rate volatility has a direct implication for cross-border trade. The exchange rate volatility restricts economic agents to engage in cross-border transactions, however, this risk can be hedged through various derivatives instruments.

Nevertheless, previous research documents inconclusive results on the exchange rate volatility and its impact on trade. For example, (Tenreyro, 2007) finds no impact of exchange rate on trade flow. (Bahmani-Oskooee and Gelan, 2018) and (Asteriou et al., 2016) report similar findings in the long-run for African countries and MINT[1] countries, however, exchange rate volatility exhibits a casual relationship in the short-run both for import and export demand. In contrast to the aforementioned results, (Sharma and Pal, 2018) assess the impact of exchange rate volatility on cross-border trade of the Indian economy with China, Japan, USA, and Germany. They report mixed results for the short-run, however, nominal exchange rate volatility dampens the performance of export. Hassan and Tufte (1998) report similar findings for the Bangladeshi economy.

[1] MINT represent countries of Mexico, Indonesia, Nigeria, and Turkey.

Blue stream discusses the models to forecast the exchange rate volatility (Anjum and Malik, 2020; Ding et al., 2020; Leung et al., 2017; Taylor, 1987; Vilasuso, 2002) and the impact of exchange rate volatility on oil prices (Chen et al., 2022; Dai et al., 2020; Salisu & Mobolaji, 2013a; F. Wen et al., 2018a; Zhang et al., 2008a).

As noted above, exchange rate volatility plays a very critical role in driving the economies and financial markets, thus, it is imperative to correctly quantify and forecast the exchange rate volatility (Anjum & Malik, 2020b). Earlier studies have mostly incorporated Value at Risk (VAR) based GARCH family models. For example, (Vilasuso, 2002) shows that FIGARCH models are better at forecasting exchange rate volatility than GARCH and IGARCH models. By using GARCH models, (Leung et al., 2017) investigate the spillover equity markets of Tokyo, London, New York, and their respective exchange rates (JPY, GBP, USD, EURO) for the period of 2001 to 2013. They show an extreme spillover during global financial crises, however, this spillover is mainly determined by fundamental and pure contagion. The extreme spillover in crises times is further evident in the recent studies which have also incorporated GARCH-based models to understand the spillover of systemic risk in the banking industry (Batten et al., 2022) and bond markets (Choudhury et al., 2022; Kinateder et al., 2022).

Similarly, (Anjum and Malik, 2020) attempt to forecast the declines in the USD exchange rate and find higher kurtosis due to exchange rate volatility along with the creation of upward bias in the persistence of estimated volatility. They further consider the GARCH as the best model to quantify the VAR. In contrast, (Ding et al., 2020) assess the impact of RMB internationalization to forecast the RMB exchange rate volatility. They incorporate genetic programming (GP) to forecast the exchange rate volatility of RMB and reveal improved prediction of RMB/EURO and RMB/USD as compared to GARCH models which failed to incorporate internationalisation effect.

A strand of literature within this stream has also identified oil-exchange rate nexus to be anything but a stable and bi-dimensional relationship. Being a key strategic resource, several factors affect oil prices and one of them is exchange rate volatility. This is more crucial for oil-importing countries with their fate dependent on foreign reserves. In this regard, (Zhang et al., 2008) identify the depreciation of USD as the key factor in driving international crude oil prices, especially in the long-run but with limited impact in the short-run. While (Wen et al., 2018) report a strong impact of USD exchange rate on crude oil prices in the short-run. Similarly, (Salisu and Mobolaji, 2013) investigate the spillover effect of oil prices and USD/Nigerian exchange rate. They report a bidirectional relationship between oil prices and the forex market of Nigeria i.e. the increase in oil prices results in depreciation in Nigerian currency against USD while depreciation in USD may increase the oil prices. (Donkor et al., 2022) report similar findings. This bidirectional relationship is more stronger during crisis times (Malik & Umar, 2019).

Yellow stream identifies how economic policy uncertainty (EPU) can influence the volatility of the exchange rate (Bartsch, 2019a; Bush & López Noria, 2021a; Chen et al., 2020a; Kisswani & Elian, 2021; Krol, 2014a; Sohag et al., 2022a). The increase in EPU increases the exchange rate volatility (Bush & López Noria, 2021b). In this regard, (Krol, 2014) assesses the impact of EPU

on exchange rate volatility in industrial and emerging economies. The results suggest that both US and domestic EPU increase the exchange rate volatility with a more pronounced effect of domestic EPU for emerging economies. The frequency of data also affects the relationship between EPU and exchange rate volatility. For example, exchange rates are more responsive to any economic policy-related changes than the monthly or yearly data detect (Bartsch, 2019b).

Furthermore, (Chen et al., 2020) document the asymmetric relationship between EPU and exchange rate volatility in China with a positive impact of EPU on exchange rate volatility and that the relationship is an inverted U-shape. The recent Russian-Ukraine war has caused a serious disruption around the globe with the increase in energy and commodity prices which subsequently transmit shocks into forex markets both in developed and emerging economies. The various EPU indices show an upward trend with serious implications for the financial markets[2]. (Sohag et al., 2022) empirically show that Russian EPU has increased, however, it appreciates Russian ruble which is probably due to the fact that the Russian government has made it mandatory to pay oil payments in local currency.

The purple cluster takes into account the models to price the currency options. The seminal work of (Heston, 1993) introduced a closed-form model for European call options with the application in currency and bond options. The model shows that the correlation between asset price and its volatility is the main determinant of skewness in returns. While (Bates, 1996) proposes a method to price American option based on USD/Deutsche mark and argue that stochastic volatility does not explain the *"volatility smile"*. In a similar line of research, recent studies have employed fractional Brownian motion (K.-H. Kim et al., 2019) and a partial differential approach coupled with Mellin transform method (Jeon & Kim, 2022) to price currency options.

3 Data and methodology

3.1 Data

Through this research, we intend to explore if the geographical proximity lead to exchange rate spillover or not. To meet our research objectives, we have selected two regions namely The South Asian Association for Regional Cooperation – 5 (SAARC5) and Association of Southeast Asian Nations - 4 (ASEAN4) as sample. The SAARC region originally includes eight countries including Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka. However, we have only selected five currencies as sample for SAARC countries including Bangladeshi Taka (BDT), Indian Rupee (INR), Maldivian Rufiyaa (MVR), Pakistani Rupee (PKR) and Sri Lankan Rupee (LKR). The Afghanistan's Afghani is excluded as the data is not consistently available. Moreover, since Bhutanese Ngultrum and Nepalese Rupee are pegged with INR, there is no point in separately exploring their spillover with the other currencies. Nevertheless, we estimated the

[2] https://voxeu.org/article/impact-war-ukraine-economic-uncertainty

spillover of these currencies with INR and found perfect dynamic correlation[3]. This finding is supported by (Sehgal et al., 2017) in the existing literature. Asean4 currencies include Indonesian Rupiah (IDR), Malaysian Ringgit (MYR), Philippine Peso (PHP) and Thai Bhat (THB). To perform the estimations, we use the daily data of sampled exchanges rates (against the US dollar). The sample period is influenced by the exchange rates data availability concerns and covers the period from August 2008 to June 2022. The data is sourced from DataStream. We also use global factors, quantifiable measure of market risk and investors' sentiments, in our analysis to perform robustness tests. These factors include Chicago Board Options Exchange (CBOE) Volatility Index (VIX), CBOE Crude Oil Volatility Index (OVX) and CBOE Gold Volatility Index (GVZ). The summary statistics for global factors are available at (Anwer et al., 2022a).

[table 1]

We first highlight the respective exchange rate regimes, in line with (IMF, 2018), for the sampled currencies (table 1). It can be observed that four of the SAARC5 countries follow *soft peg* (in shape of stabilized arrangement or crawl-like arrangement) while majority of the ASEAN4 countries follow *floating* regimes or market determined rates. This distinction reveals an important difference in the monetary policy orientation for both the sampled regions. The summary statistics show that IDR exhibits highest volatility followed by LKR and PKR. Most of the data series are skewed and justify our choice of a dynamic model. The unit root test show that all the data series are stationary.

The time evolution of daily exchange rates of the sampled exchange rates over the sample period (figure 1) carries important insights. Here, the increasing trend points to the devaluation of the home currency.

[Figure 4]

For SAARC5 countries (figure 4), we first notice a decline in the value of BDT from July 2010 to January 2012 owing mainly to external demand shock (Saidjada et al., 2013). Later, it shows appreciation due to high volume of inward remittances. Subsequently, during the years 2016-2018, we notice sizeable depreciation of BDT mainly due to lower volume of inward remittances and rising imports. INR weakened in the begging of the year 2012 mainly due to withdrawal by foreign institutional investors, strengthening of USD globally, widening current account deficit, and declining balances of other capital flows like foreign direct investment and external borrowings[4]. In addition to the gradual decline for the sample period, LKR dropped in value at the start of year 2022 due to the worst balance of payment crisis this region has ever experienced. MVR experienced. MVR also experienced deterioration in exchange rate after 2011 due to the rising

[3] The results are not reported here but available on request.

[4] https://moneymint.com/indian-rupee-depreciation-2012/

inflation and Maldives' adoption of more flexible exchange rate system (Hassan & Gharleghi, 2015). PKR is an interesting case, as monetary authorities in Pakistan are often blamed to keep exchange rates artificially high through active market interventions. This approach has historically resulted in widening balance of payments gap. In 2017, therefore, the monetary authorities had to let PKR face devaluation to meet the conditions of International monetary fund for a bailout package[5]. We therefore observe a considerable drop in the value of PKR from the December 2017 to June 2022.

[Figure 5]

We observe a somewhat different picture for ASEAN4 countries (figure 5). The movement of IDR shows an unusual episode of high exchange rate appreciation in the year 2011 due to unusual capital inflows (Warjiyo, 2013). Nevertheless, the situation reversed due to a) worsening of the global financial crisis leading to downgrade of US Bond ratings and b) Greek debt crisis. The situation led to huge capital outflows from Indonesia and heavy pressure on exchange rate. MYR experienced appreciation starting from Q4 2009 due to large capital inflows to Malaysia and other emerging economies. This capital movement was result of quantitative easing and a de facto zero interest rate policy implemented by US and other advanced countries to combat the outcomes of GFC (Umezaki, 2019). It can be noticed that MYR started declining from May 2013, an outcome of the outflow of foreign funds from Malaysia and other emerging economies after the discontinuation of quantitative easing by US federal reserve bank and increase in interest rates at developed economies. The situation further worsened for MYR after sharp cut in crude oil prices.

The story is somewhat similar for PHP and THB, recording appreciation against USD in the aftermath of GFC. Interestingly, both the currencies manifest a surge in their values due to strong economic credentials and positive balance of payment.

[table 2]

We also construct correlation matrices for both the regions (table 2). It is observed that no currency pair shows high correlation. This finding provides initial evidence of the fact that regional proximity does not lead to exchange rate spillover. However, this finding is arbitrary, and we need to imply a dynamic model to find out the answers to our research questions.

3.2 Empirical framework

To assess the spillover among exchange rates of SAARC5 and ASEAN4 regions, we employ Continuous Wavelet Transform (CWT), Wavelet Transform Coherence (WTC) and Partial Wavelet Coherence (PWC). The wavelet methodology is suitable to address our research questions owing to its ability to capture non-linear associations between multiple exchange rates. In addition,

[5] https://www.bloomberg.com/news/articles/2018-07-16/pakistan-said-to-devalue-asia-s-worst-performing-currency-again#xj4y7vzkg

to perform wavelet analysis, the data series need not be stationery or normal (Vacha & Barunik, 2012). Moreover, the events localized in time may be captured efficiently and the analysis is performed from a time-frequency perspective. Finally, the direction as well as the strength of the linkage can be identified and the distinction between short, medium, and long term associations can be made at the same time.

We first apply wavelet decomposition on the return series (Grinsted et al., 2004) to capture co-movements in time–frequency space and estimate continuous wavelet transform (CWT) by applying wavelet coherency. CWT may be expressed as

$$H(scale, position) = \int_{-\infty}^{\infty} x_t \lambda(scale, position, time) dt \quad (1)$$

CWT estimates several wavelet coefficients *H*, that are functions of scale and position and may assume any values compatible with location of the time series x_t. The variances of the wavelet coefficients of the random process, computed within each scale, formulate the *Wavelet Spectrum.* CWT maps the correlation among two series in the form of *Wavelet Power Spectrum (Coherency)*, displayed through a two-dimensional figure, to easily identify and interpret the patterns or hidden information. We may define the squared wavelet coefficient as

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

In equation 3, *'s'* represents the smoothing parameter. In the instances when there is no smoothing, the wavelet coherence will be equal to one. The squared wavelet coherence coefficient falls in the range $0 \leq R^2(u,s) \leq 1$.

To study the co-movements among two exchange rates while controlling for the common effects of global factor*(s)*, we employ *Partial Wavelet Coherence* (PWC). It can be represented as

$$RP^2(a,b,x) = \frac{|R((ab)-R(a,x|-R(a,b)|^2}{[1-R(a,x)]^2[1-R(b,x)]^2} \quad (3)$$

Where *'a'* and *'b'* represent the sampled exchange rates and *'x'* signifies the global factor.

4 Results and discussion

[Figure 6]

We first show the movement of each currency on Wavelet spectrum plots in the frequency bands and time scales. The horizontal axis shows the time component (from 08-Apr-2008 to 08-Jun-2022). The breakup of values on the horizontal axis is as follows: 500 equivalent to 27-Jul-2010; 1,000 equivalent to 19-Jul-2012; 1,500 equivalent to 17-Jul-2014; 2,000 equivalent to 12-Jul-2016; 2,500 equivalent to 06-Jul-2018; 3,000 equivalent to 01-Jul-2018 and 3,000 equivalent to 01-Jul-2020. The detailed timeline is made available in figure 1 for the facilitation of the readers. The frequency component is displayed on vertical axis. The values range from scale 1 (a day) up to scale 1,024 (2.8 years). The lower (higher) scale represents the high (low-) frequency nature of the data. The thick black contours in the figures the statistical significance of wavelet power (95%

confidence level), estimated by Monte Carlo simulations using phase randomized surrogate series. The cone of influence (COI) shows distortion of the picture by edge effects. The range of power is from blue (low power) to red (high power).

We first evaluate the wavelet spectrum for SAARC countries (figure 1). For BDT, we notice cycles for 4 – 16 days frequency bands. The notable extensions of these cycles may be observed at the beginning (GFC), in August 2012 (high inward remittances) and between the years 2016-2018 (low remittances and rising imports). For INR, we notice several scattered cycles of moderate power right from the peak of GFC to the year 2014 (huge capital outflows). These cycles belong to different frequency bands and spread over several years. It appears that INR remained moderately volatile during the said period. We also observe high volatility clusters for the period Oct-2010 to Oct-2011 for LKR for high frequency band (0-8) due to short term inflow of foreign capital. MVR manifests significant above-normal volatility cycle for the same period (voluntary devaluation). PKR, for the years 2010 – 2012, we observe significantly powerful fluctuation mainly due to mounting pressure on exchanges rates due to higher demand.

[Figure 7]

Now we move to the analysis of wavelet spectrum for ASEAN4. There is a strong volatility cluster of low frequency for IDR from April 2010 to September 2012 (abnormal inflow and outflow of foreign capital). We observe several high frequency clusters of high power from August 2008 till June 2017 ('hot money' inflow/outflow). In addition, there also exists a low frequency volatility cluster from June 2014 to August 2018 (exchange rate deterioration due to declining oil prices). For PHP and THB, we observe high frequency clusters ('hot money' inflow/outflow) similar to MYR for the like period.

We now focus on our main research question, i.e., whether geographical proximity leads to the co-movement of exchange rates, or they remain detached. To understand this, we investigate the relative volatility of the sampled currencies by assessing wavelet power spectrum (coherences) of each pair of currencies. There is a color bar on the right side of the charts that indicates the degree of correlation. The red (blue) colors represent extremely high (low) absolute correlation values for $R^2(u,s)$. The charts also identify the lead-lag relationship between the currencies as well as the nature of the causality (i.e., negative or positive) by virtue of the phase-differences. Phases are designated by black arrows on the wavelet coherence figures. We may use table 3 to understand the dynamics of our wavelet power spectrum for two variables 'X' and 'Y'.

[Table 3]

[Figure 8]

Our analysis of all the pairs of SAARC currencies reveals that except for very rare, scattered volatility islands, no co-movement of exchange rates exists between SAARC exchange rates (figure 8). For instance, BDT Vs. LKR pair shows co-movement in the similar direction for low frequency trading band for the period 2011-2012 and high frequency trading band for the period

2014-2017. Also, PKR Vs. MVR pairs shows co-movement in the similar direction till the year 2018. Interestingly, after Pakistan's voluntary devaluation of PKR following IMF pressure, no co-movement exists between both the currencies (PKR vs. MVR). The results are in line with (Sehgal et al., 2017), who blame low regional trade intensity as well as low intra-regional equity portfolio flows for the lower connectedness among the countries of SAARC region.

[Figure 9]

For ASEAN 4, the story is not much different. There are rare instances of pairwise co-movement. For example, MYR Vs. IDR exhibited positive co-movement for the period 2014-2016. Similarly, MYR Vs. THB and PHP Vs. MYR pairs also show volatility islands. In all these cases, MYR is leading. Finally, we observe positive connectedness for PHP Vs. THB pair for low frequency trading. Here, PHP is leading the exchange rate movements. Our results support the findings of Shahrier (2022), who found evidence of scattered incidents of exchange rates connectedness among ASEAN4 currencies during COVID19.

[Figures 10 and 11]

[Appendix figures 1 to 4]

We use PWC approach to perform robustness tests and use USEPU, OVX and GVZ as controlling variables. First, the pairwise co-movement of SAARC5 and ASEAN currencies is estimated using USEPU as controlling variable. The results reported through figures 10 and 11 substantiate the notion that our main results are robust. In addition, the estimations are performed using OVX and GVZ as controlling variables and results are reported in appendix. As these findings are qualitative similar to the results of our baseline estimations, we are confident that our results are robust.

Our findings contradict the findings of Kim et al. (2013) who reported significantly lower and negative correlation among the selected Asian currencies and the Japanese Yen. Our results also contradict the findings of Pandey and Sehgal (2018), who examine currency linkages in East Asian countries that include ASEAN+6 countries. Their results indicate that currencies in East Asian countries have 'overlapping time cycles' and exhibit diverse degrees of currency co-movement. We partially support the results of Mishra et al. (2020), who examine spillover among major trading partners of India and find that time-domain connectedness is relatively stronger than frequency domain.

5 Conclusion

In view of growing scholarly preponderance of Asian currency connectedness, this study adds to the literature on foreign currency dynamics in two important regions namely SAARC and ASEAN. We use Wavelet methodologies to study how the co-movement pattern of the currencies of the member countries. The results of the Wavelet spectrum on SAARC as well as ASEAN exhibit strong time-varying cycles of short- and long-term volatility. These effects are presented by several events including excessive capital inflows and outflows in the aftermath of the global financial

crisis, and low frequency volatility due to oil market crisis and geopolitical tensions. Wavelet coherence tests show that the pairs of SAARC currencies did not reveal any significant co-movement. Similar results are found for ASEAN countries. There are rare volatility and co-movement among currencies. Malaysian Ringgit is leading the co-movement in most cases.

Our contributions forward two implications. First, currencies in SAARC region do not spillover much. Their value is primarily driven by intra-market characteristics, including economic growth, market expectation, policy change, and internal market intervention. No single currency drives others. Other than extreme international events, mostly internal factors are important while determining the currency value. Investment in and diversification of these currencies do not yield much benefit. Secondly, policymakers on these currencies play the bigger role as these currencies are generally supply-driven. Most of these countries follow soft peg. Therefore, indirect market intervention may save the currencies from shocks from uncertainty. Strengthening internal governance and developing better intra-regional trade superstructure are expected to have positive impact on currency stability, thus on economic growth.

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Table 1: Descriptive Statistics

	Monetary Regime	Mean	P50	SD	P25	P75	Max	Min	Skew	Kurt	ADF	PP
	SAARC5											
BDT	Crawl-like arrangement	77.41	77.41	5.59	75.73	82.84	87.38	67.06	-0.54	2.09	-15.051***	-4,373.1***
INR	Floating	61.23	63.74	10.35	50.87	69.57	77.60	42.43	-0.30	1.74	-14.243***	-4,251.9***
LKR	Crawl-like arrangement	146.81	132.91	38.00	115.91	175.38	359.19	105.42	2.36	12.50	-11.414***	-4,254.4***
MVR	Stabilized arrangement	14.64	15.19	1.04	14.95	15.21	15.41	12.00	-1.44	3.13	-14.978***	-4,114.1***
PKR	Stabilized arrangement	112.95	103.16	30.66	88.66	138.15	198.70	71.45	0.92	2.56	-14.774***	-3,483.7***
	ASEAN4											
IDR	Stabilized arrangement	12,040	13,020	2,339	9,609	14,094	16,277	888	-0.85	4.27	-14.486***	-3,792.1***
MYR	Floating	3.71	3.77	0.49	3.23	4.16	4.48	2.92	-0.12	1.41	-14.896***	-4,076.1***
PHP	Floating	47.13	47.14	3.53	44.05	50.38	53.97	40.53	-0.02	1.87	-16.063***	-4,180.3***
THB	Floating	32.37	32.21	1.76	30.92	33.70	36.33	28.67	0.30	2.20	-14.486***	-4,272.5***

This table provides the summary statistics of currencies from our sample countries under different exchange regimes. The BDT, INR, LKR, MVR, and PKR represent the currencies of Bangladesh, India, Sri Lanka, Maldives, and Pakistan while IDR, MYR, PHP, and THB represent the currencies of Indonesia, Malaysia, Philippines, and Thailand, respectively.

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2: Correlation Matrix

SAARC5					
	BDT	INR	LKR	MVR	PKR
BDT	1				
INR	-0.191***	1			
LKR	0.282***	0.030	1		
MVR	0.012	0.006	-0.031	1	
PKR	0.039*	0.006	0.073***	0.009	1
ASEAN4					
	IDR	MYR	PHP	THB	
IDR	1				
MYR	0.016	1			
PHP	0.007	0.093***	1		
THB	0.019	0.108***	0.174***	1	

This table provides the correlation matrix among the currencies from SAARC5 and ASEAN4 regions. The BDT, INR, LKR, MVR, and PKR represent the currencies of Bangladesh, India, Sri Lanka, Maldives, and Pakistan while IDR, MYR, PHP, and THB represent the currencies of Indonesia, Malaysia, Philippines, and Thailand, respectively.

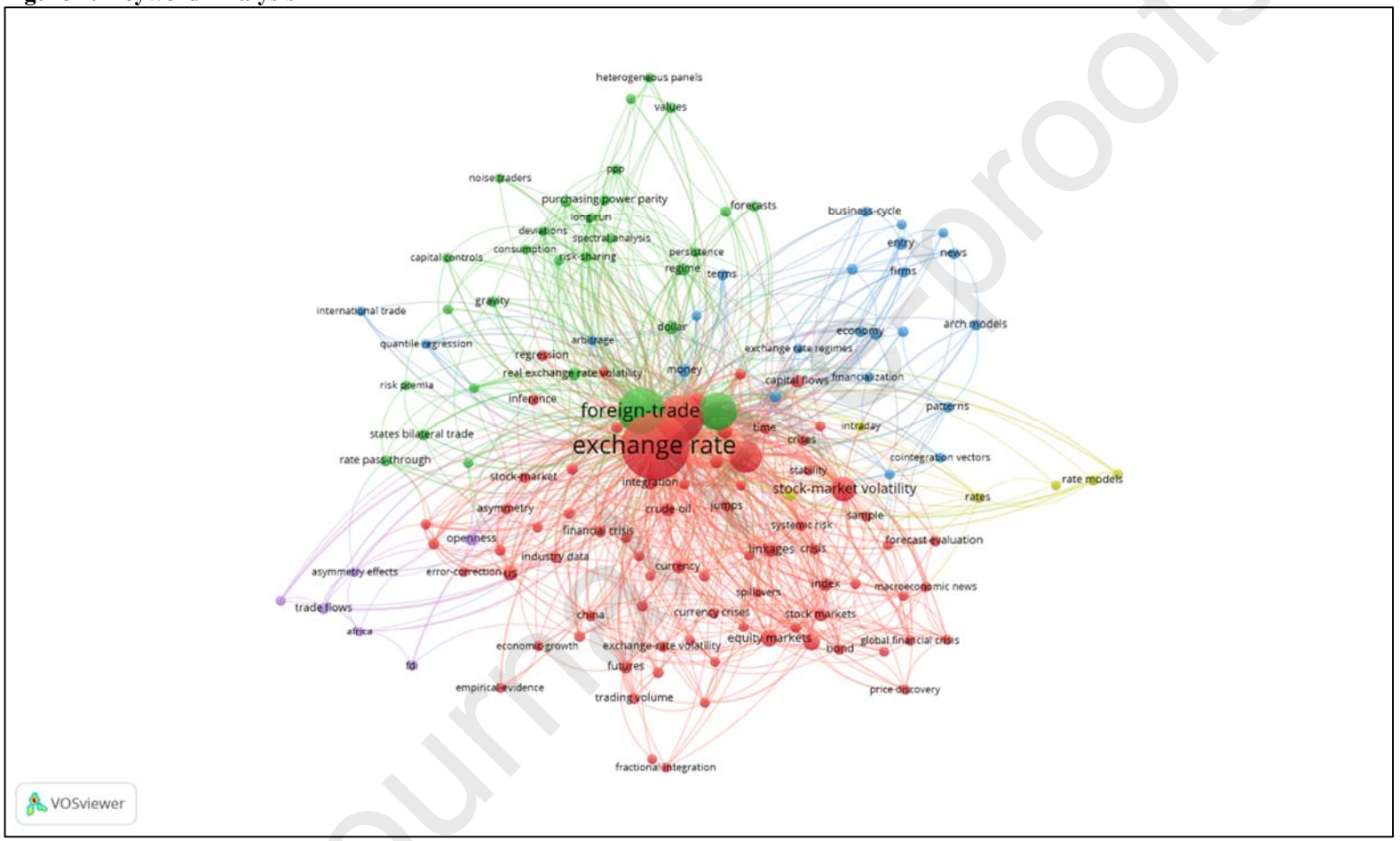
Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3: Wavelet Power Spectrum- 'X' Vs. 'Y'

Direction of arrow	Lead-Lag Relationship	Phase Difference	Nature of co-movement
Horizontal	No	Zero	Same side
Upward - Left	X leads	Out	Negative
Upward - Right	Y leads	In	Positive
Downward - Left	Y leads	Out	Negative
Downward - Right	X leads	In	Positive

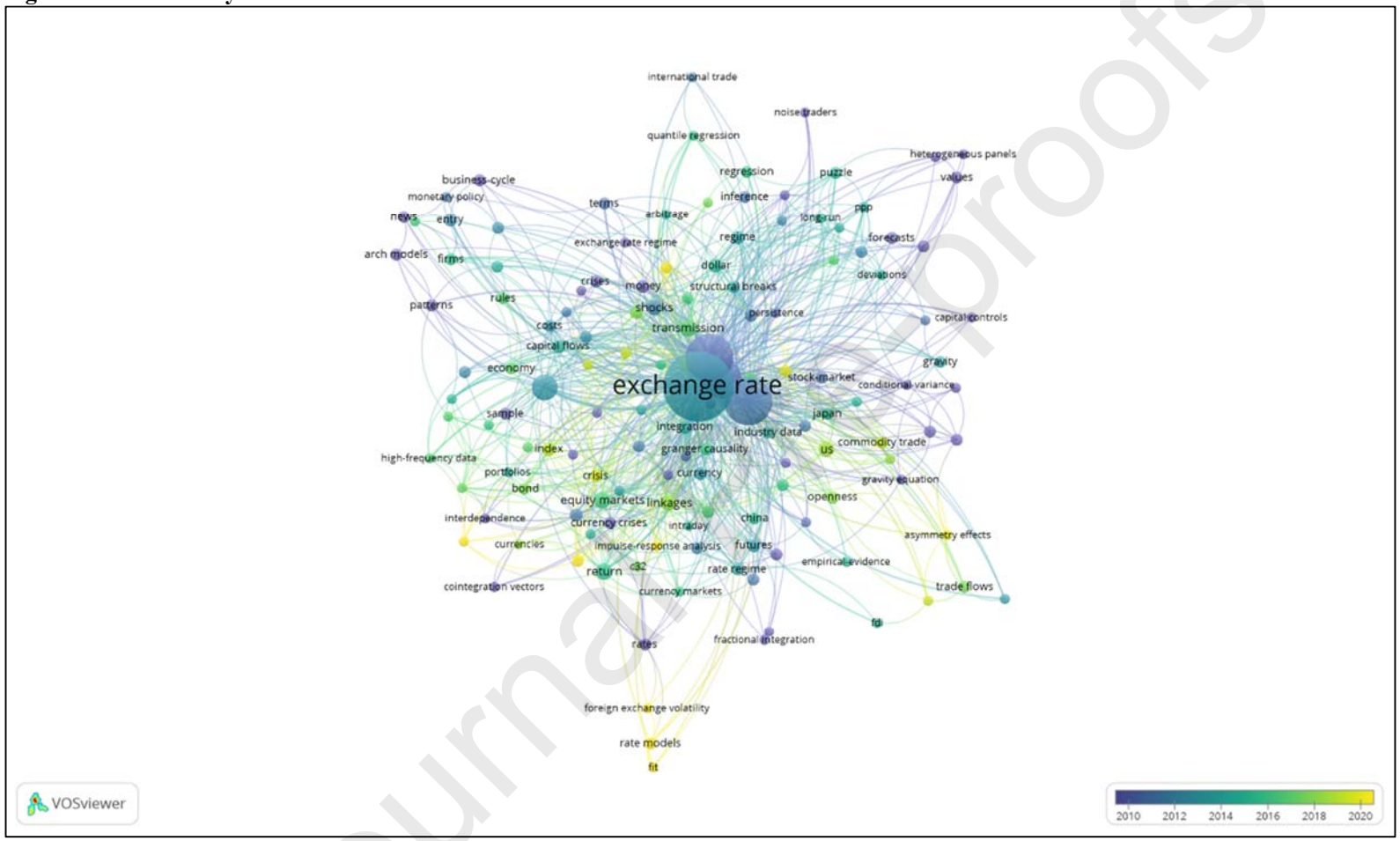
Note: This table is intended to assist the reader in interpreting the Wavelet Power Spectrum figures.

Figure 1: Keyword Analysis



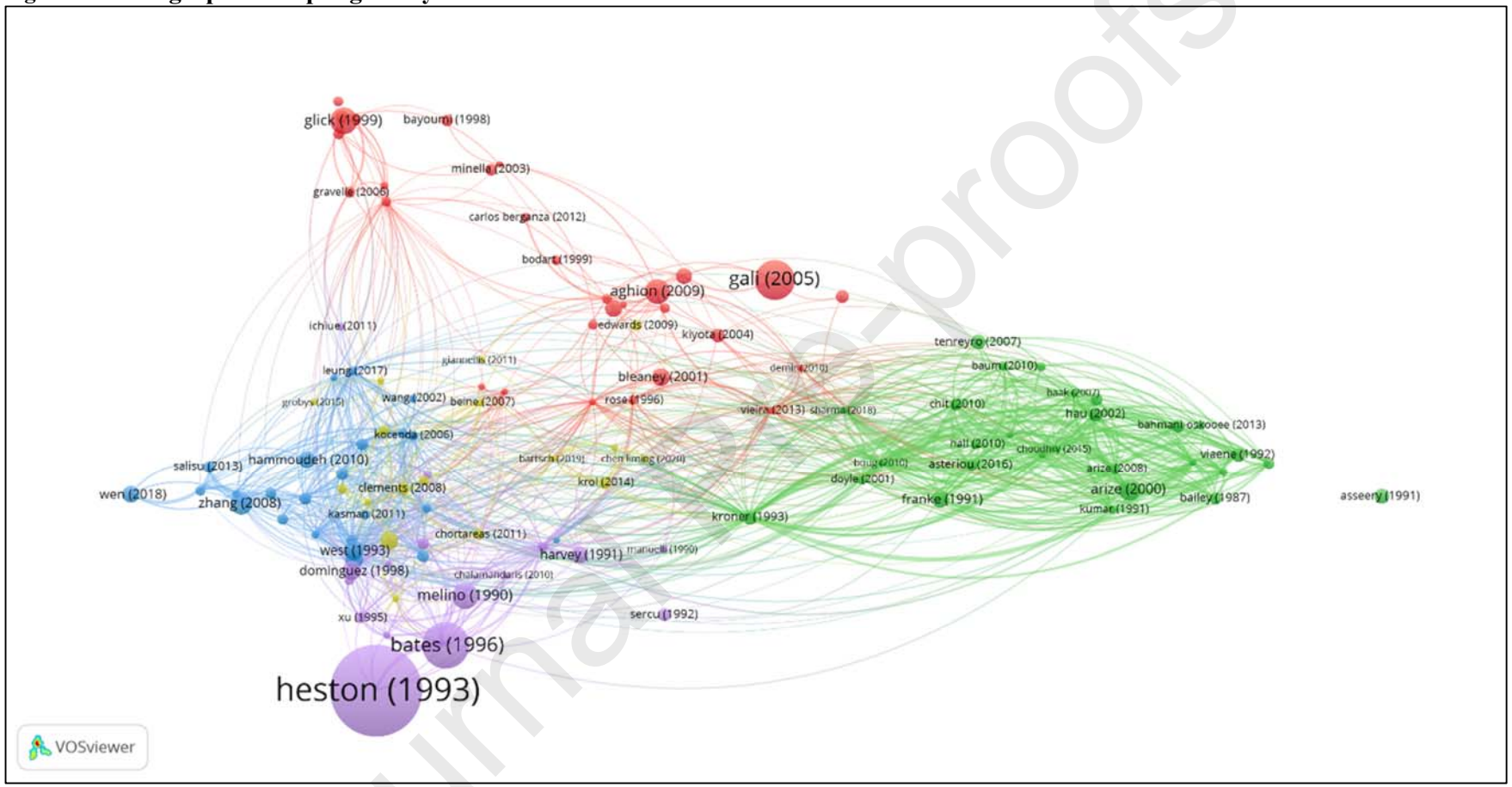
This figure presents the keyword analysis of the sampled literature within the domain of interconnectedness of exchange rates with various financial markets.

Figure 2: Trend Analysis



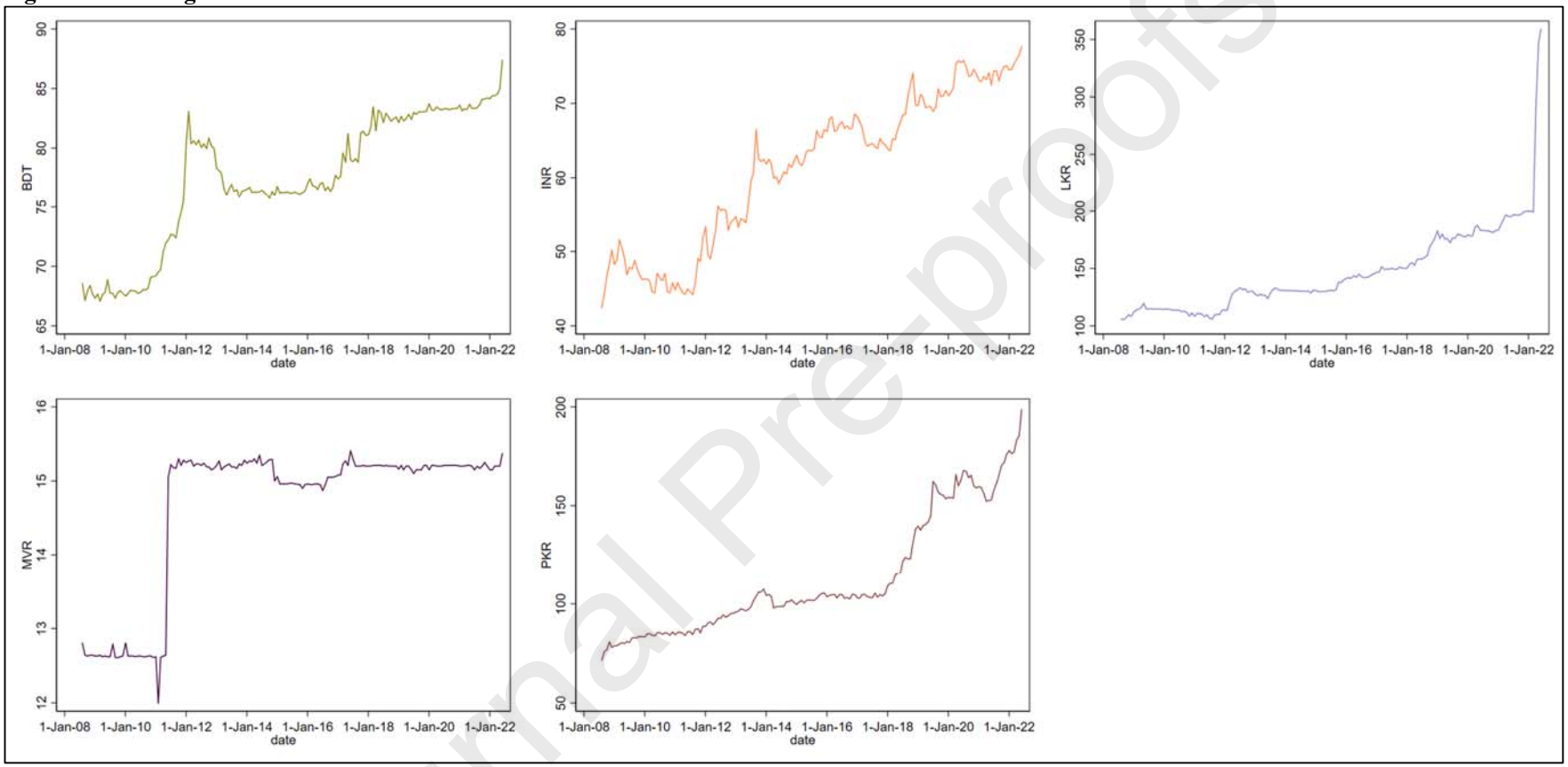
This figure presents the trend analysis across keywords, their evolution across time, and their relative weight within sampled literature.

Figure 3: Bibliographic Coupling Analysis



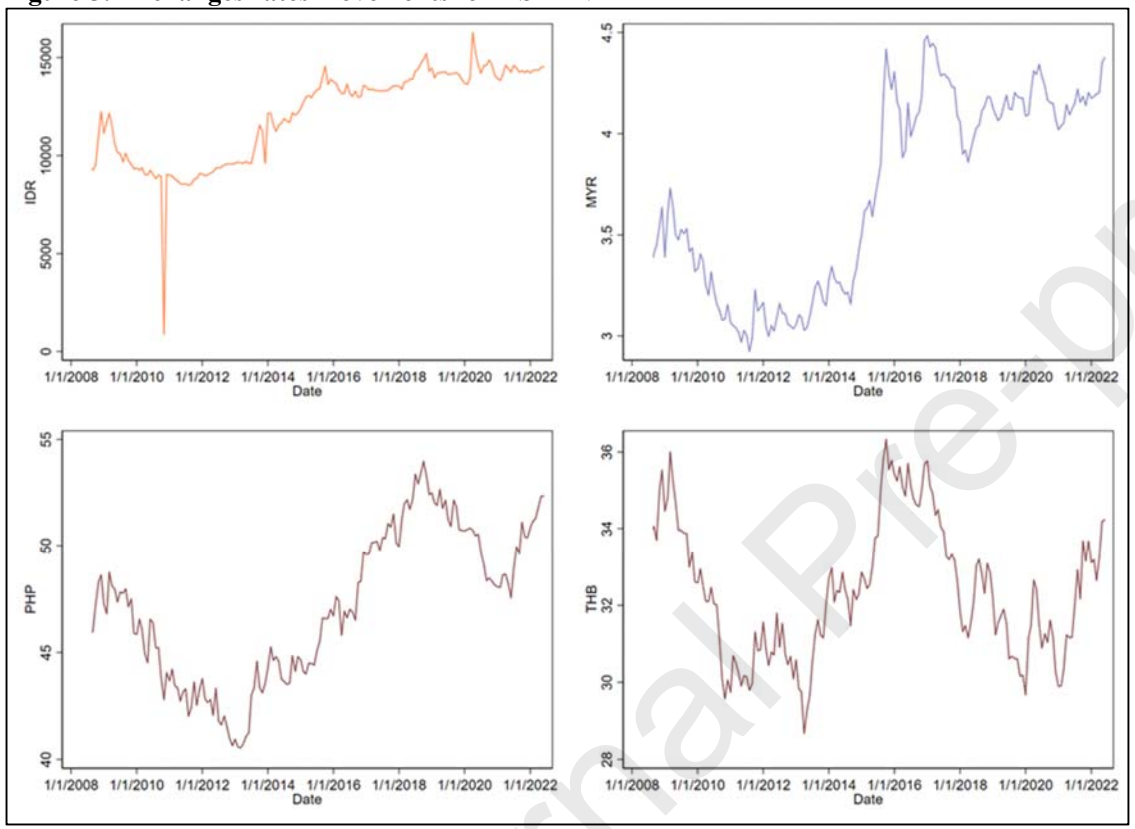
This figure presents the bibliographic coupling analysis to highlight the streams/clusters within existing literature in the domain of exchange rate volatility.

Figure 4: Exchanges rates movements for SAARC5



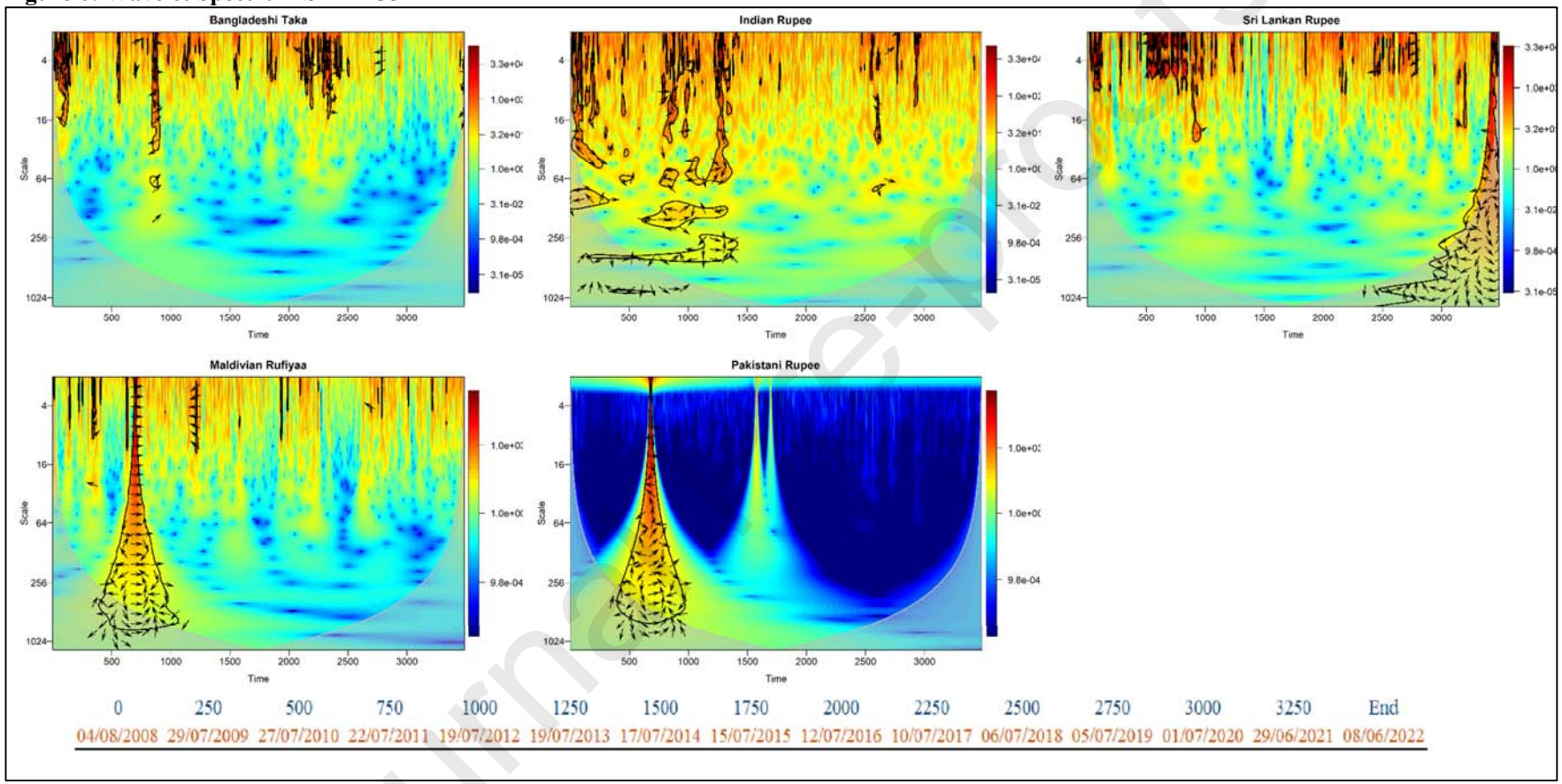
This figure describes the exchanges rates movements for SAARC5. The BDT, INR, LKR, MVR, and PKR represent the currencies of Bangladesh, India, Sri Lanka, Maldives, and Pakistan, respectively.

Figure 5: Exchanges rates movements for ASEAN4



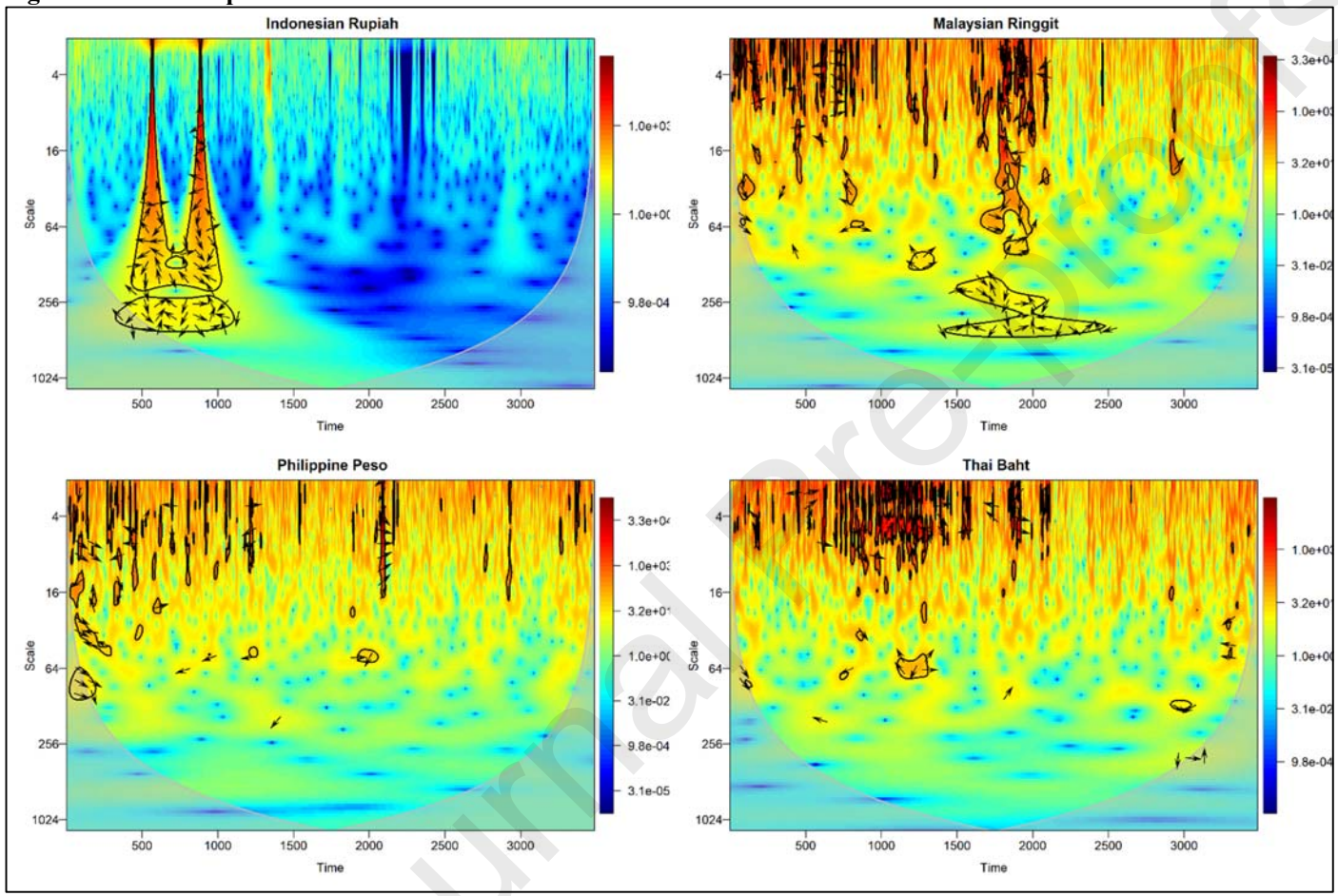
This figure presents the exchanges rates movements ASEAN4. The IDR, MYR, PHP, and THB represent the currencies of Indonesia, Malaysia, Philippines, and Thailand, respectively.

Figure 6: Wavelet Spectrum SAARC5



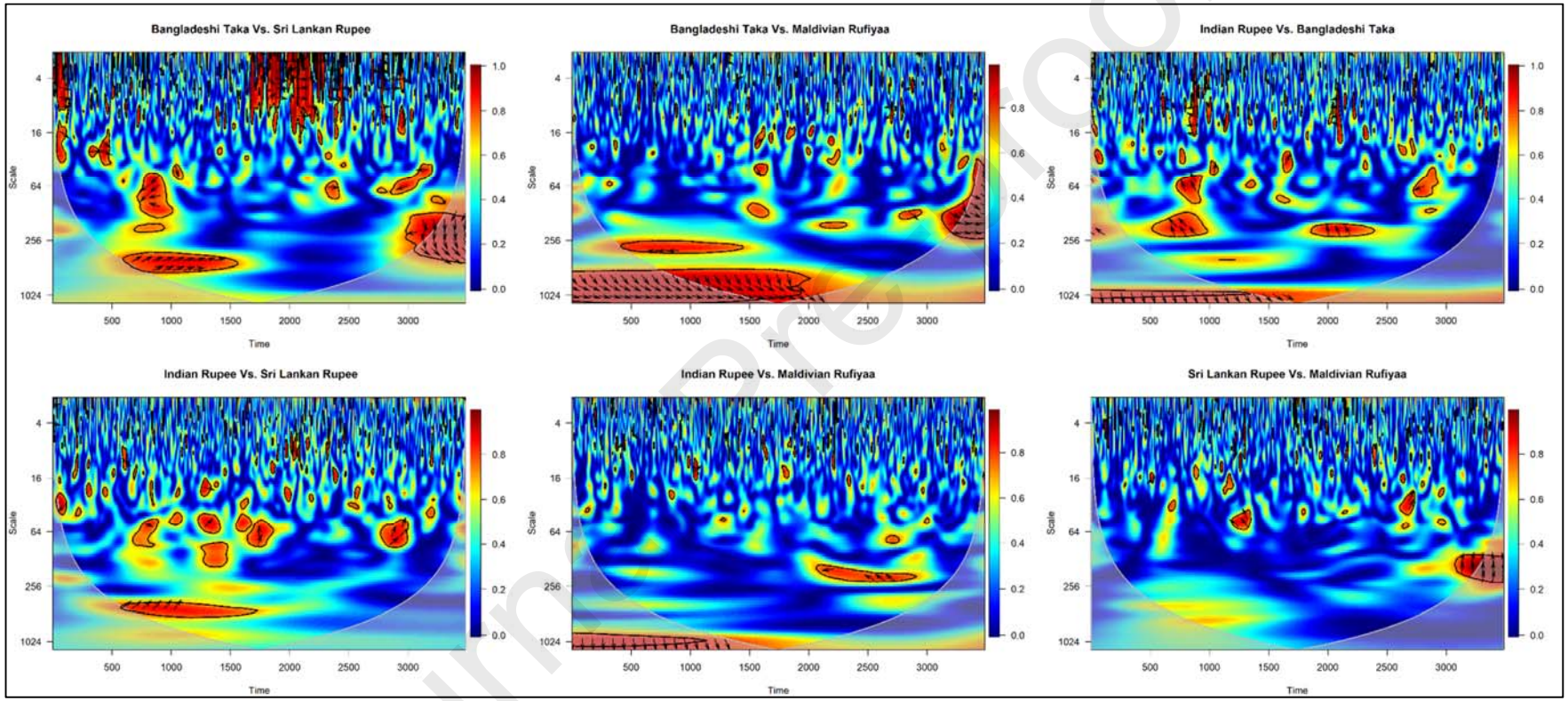
This figure evaluates the wavelet spectrum for currencies of SAARC5 countries namely Bangladeshi Taka, Indian Rupee, Sri Lankan Rupee, Maldivian Rufiyaa and Pakistani Rupee.

Figure 7: Wavelet Spectrum ASEAN4

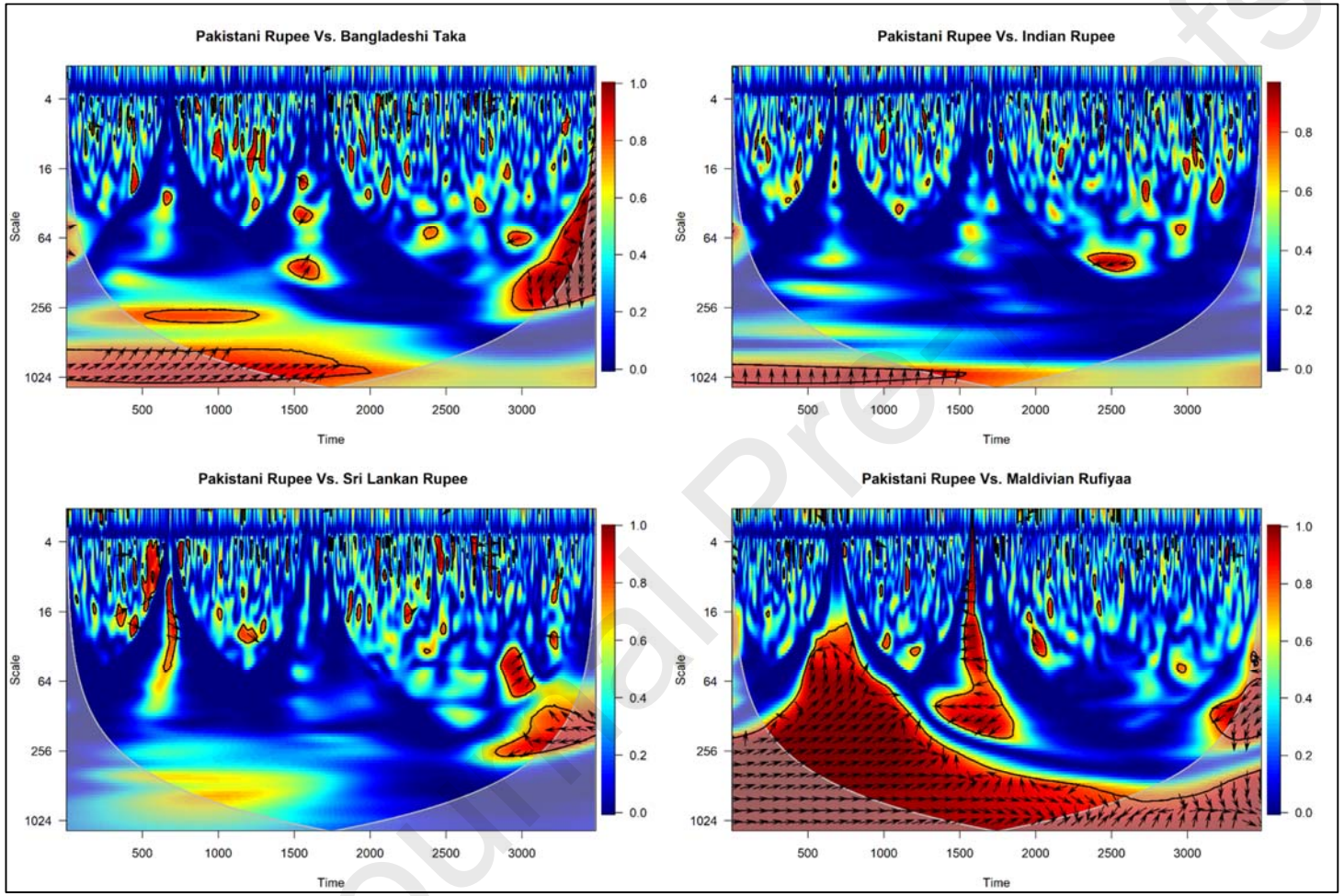


This figure evaluates the wavelet spectrum for currencies of ASEAN4 countries namely Indonesian Rupiah, Malaysian Ringgit, Philippino Peso and Thai Baht.

Figure 8: Wavelet Power Spectrum SAARC5
Part a

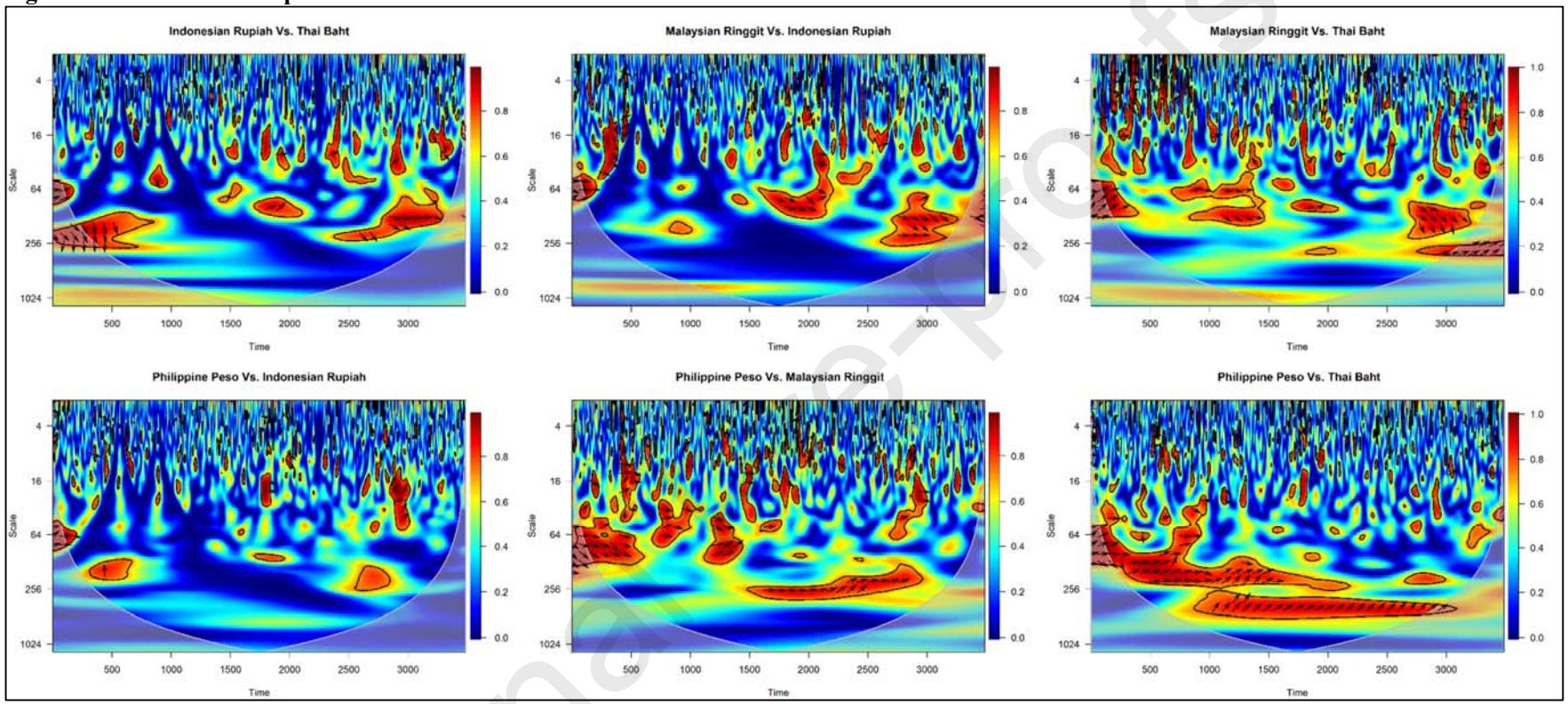


Part b



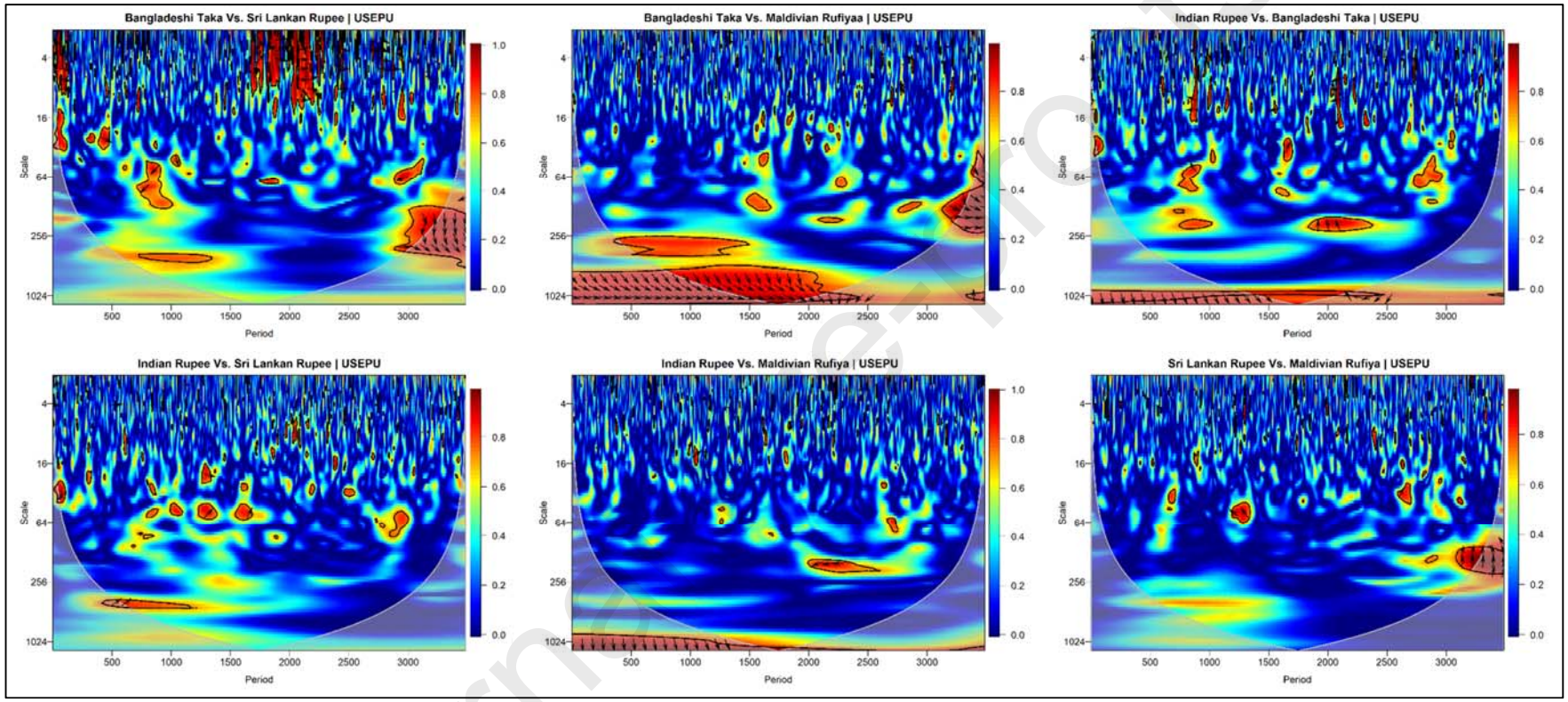
This figure applies wavelet power spectrum to present the pairwise co-movement of currencies from SAARC5 countries namely Bangladeshi Taka, Indian Rupee, Sri Lankan Rupee, Maldivian Rufiyaa and Pakistani Rupee.

Figure 9: Wavelet Power Spectrum ASEAN4

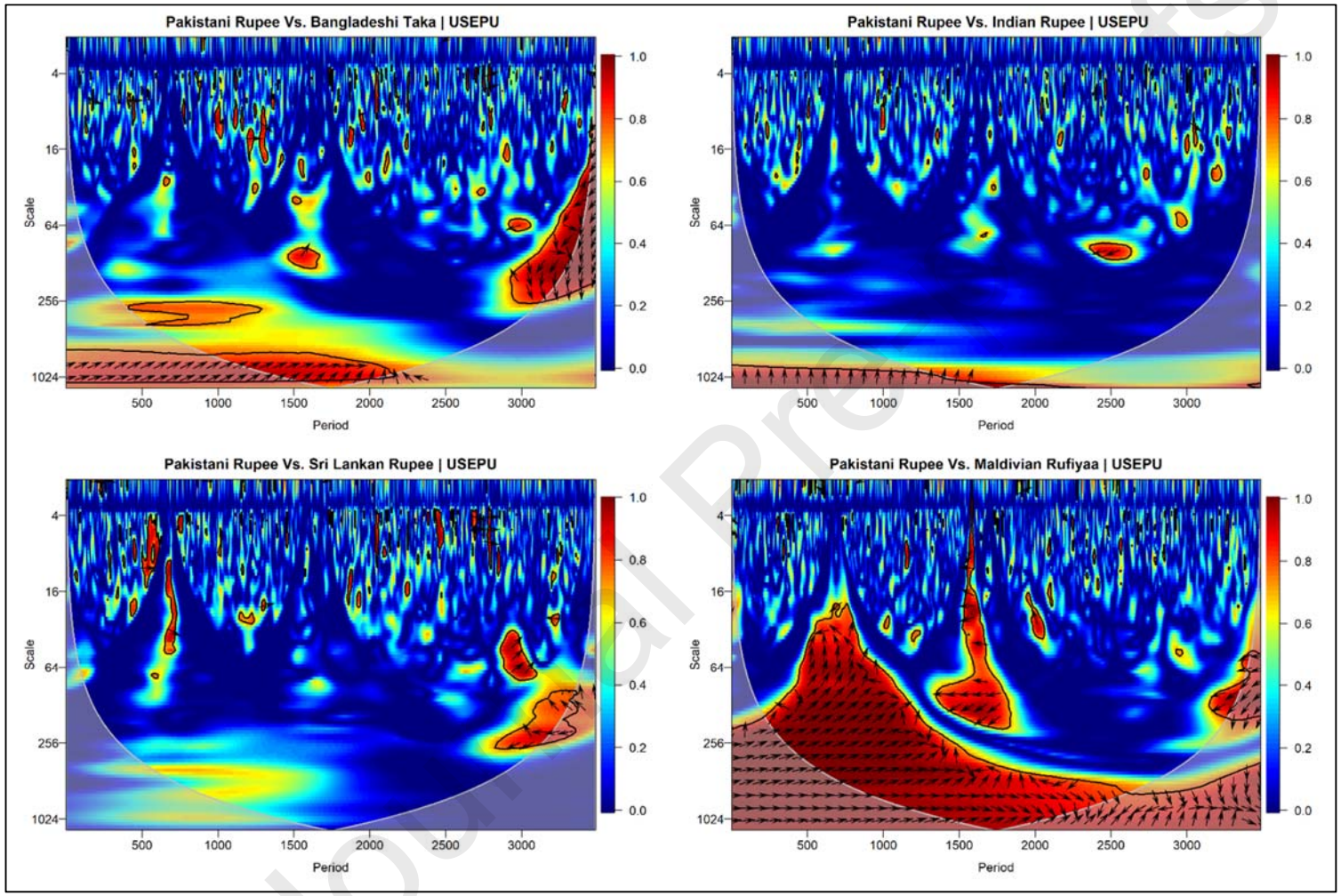


This figure applies wavelet power spectrum to present the pairwise co-movement of currencies from ASEAN4 countries namely Indonesian Rupiah, Malaysian Ringgit, Philippine Peso and Thai Baht.

Figure 10: Partial Wavelet Coherence SAARC5 (US Economic Policy Uncertainty as controlling variable)
Part a

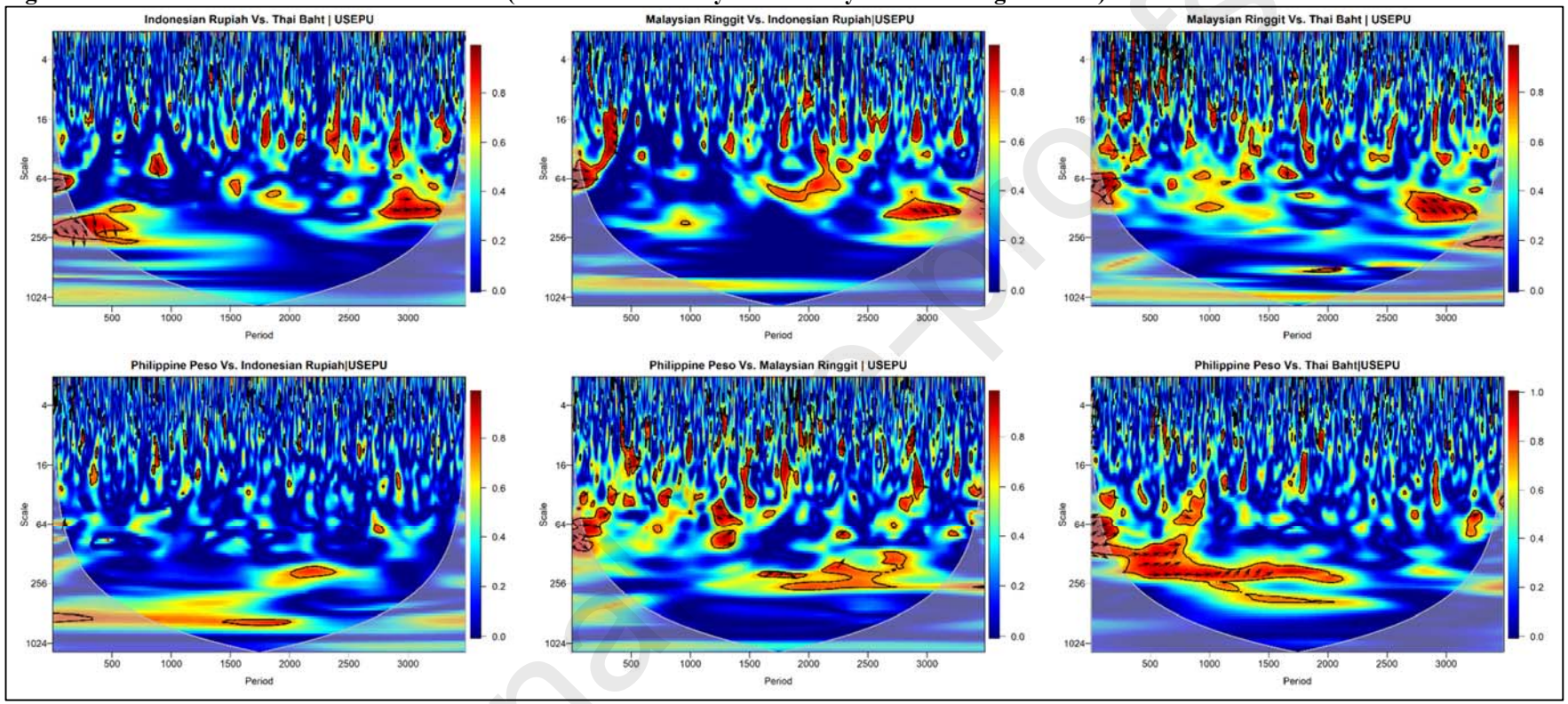


Part b



This figure applies partial wavelet coherence by using US economic policy uncertainty as controlling variable to present the pairwise co-movement of currencies from SAARC5 countries namely Bangladeshi Taka, Indian Rupee, Sri Lankan Rupee, Maldivian Rufiyaa and Pakistani Rupee.

Figure 11: Partial Wavelet Coherence ASEAN4 (US Economic Policy Uncertainty as controlling variable)

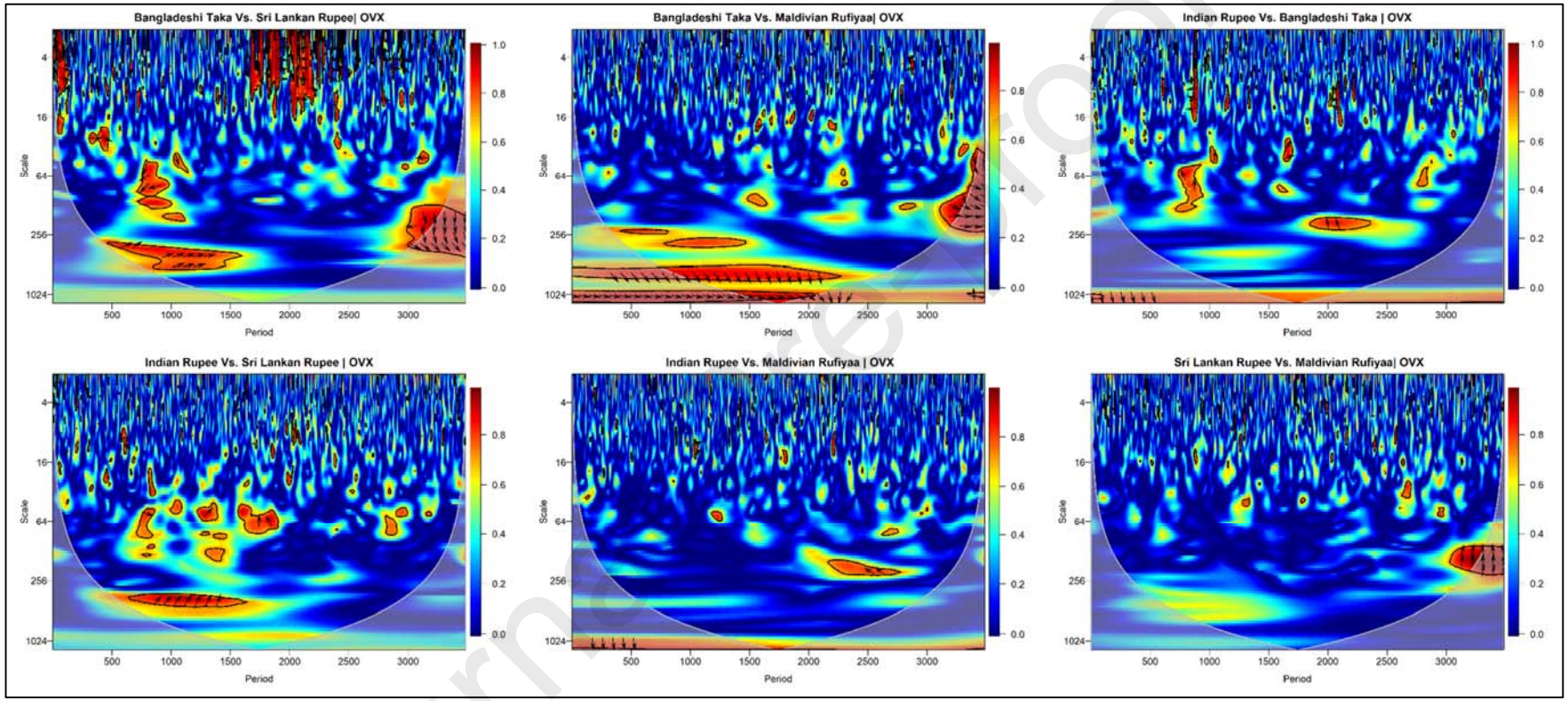


This figure applies partial wavelet coherence by using US economic policy uncertainty as controlling variable to present the pairwise co-movement of currencies from ASEAN4 countries namely Indonesian Rupiah, Malaysian Ringgit, Philippine Peso and Thai Baht.

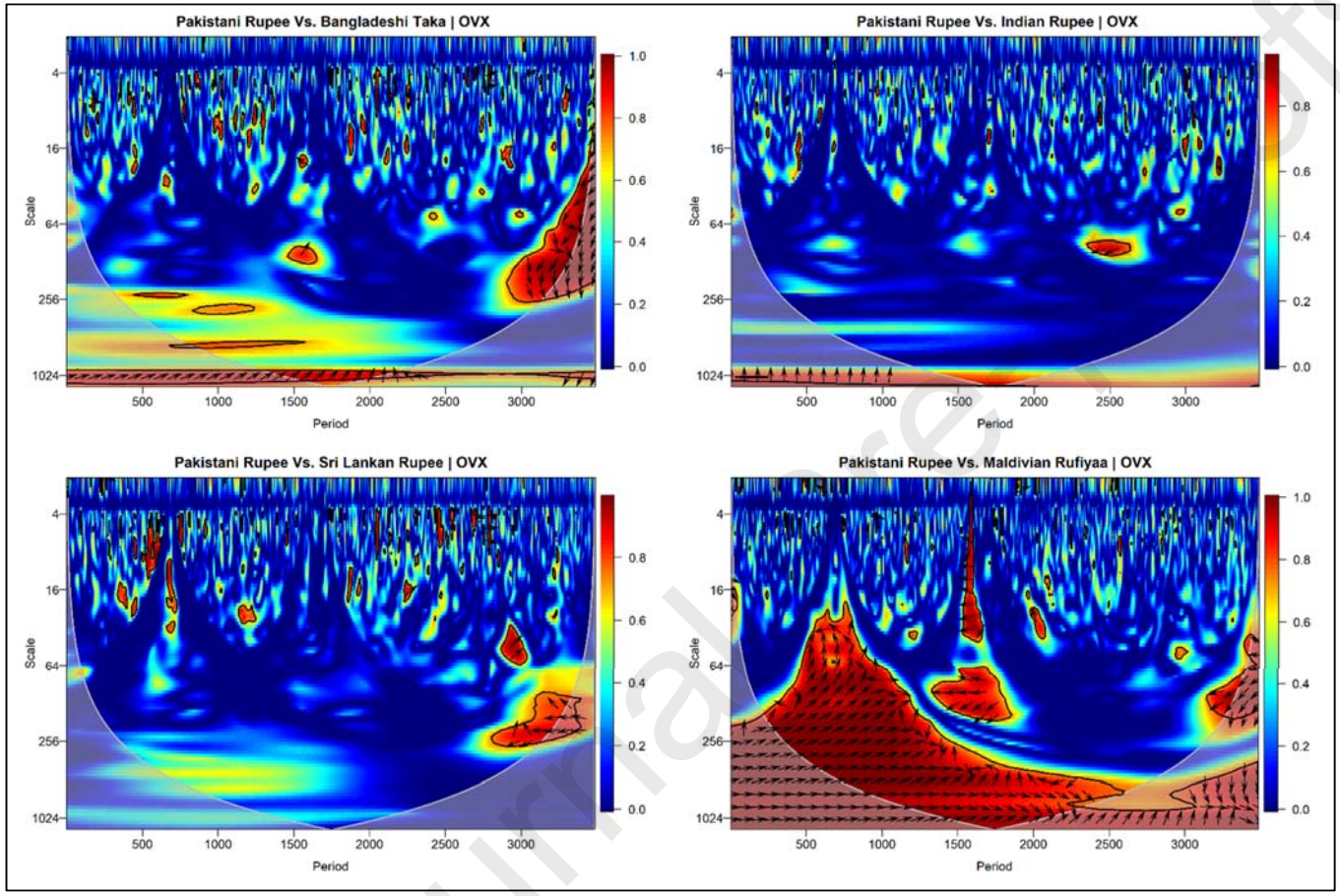
APPENDIX

Figure 1: Partial Wavelet Coherence SAARC5 (CBOE Crude Oil Volatility Index as controlling variable)

Part a



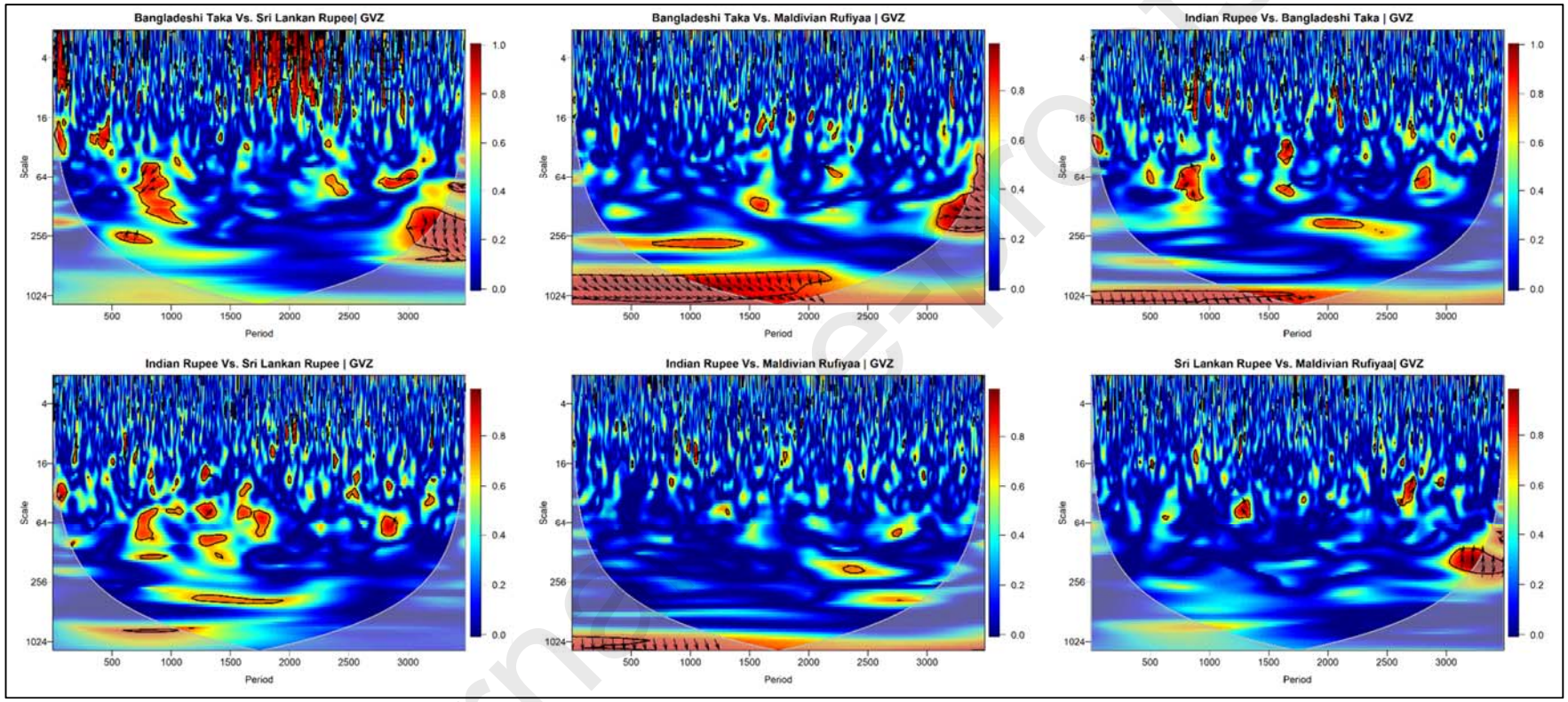
Part b



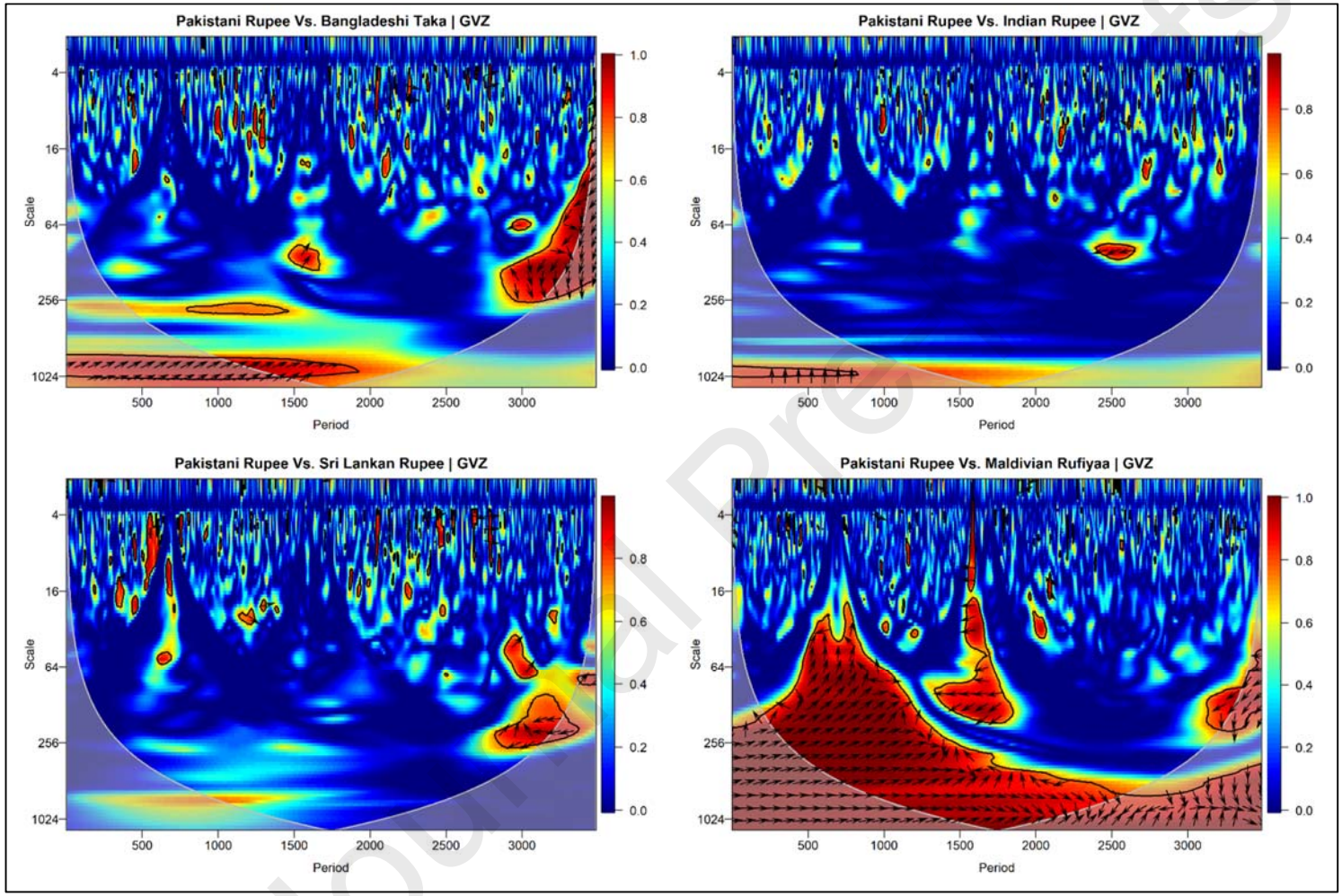
This figure applies partial wavelet coherence by using CBOE Crude Oil Volatility Index as controlling variable to present the pairwise co-movement of currencies from SAARC5 countries namely Bangladeshi Taka, Indian Rupee, Sri Lankan Rupee, Maldivian Rufiyaa and Pakistani Rupee.

Figure 2: Partial Wavelet Coherence SAARC5 (CBOE Gold Volatility Index as controlling variable)

Part a

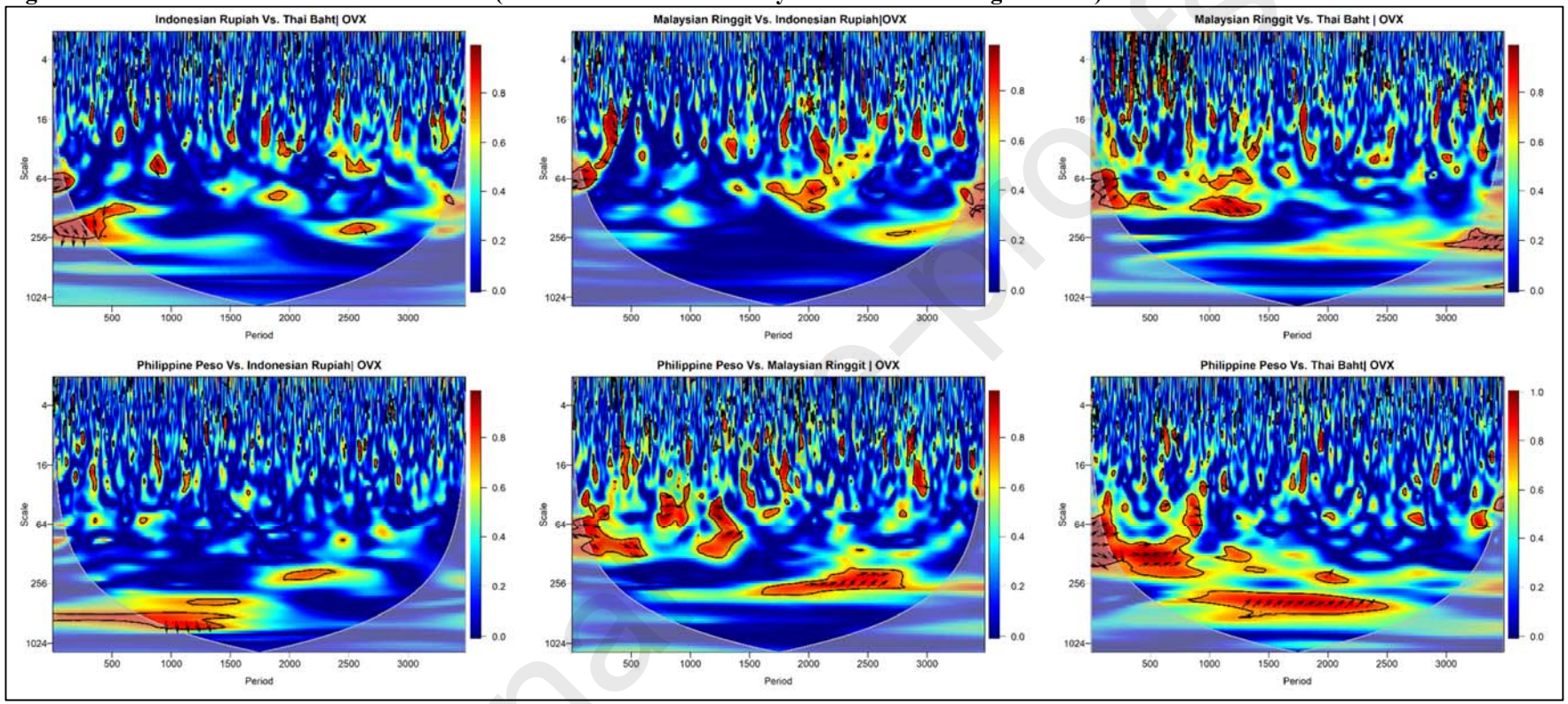


Part b



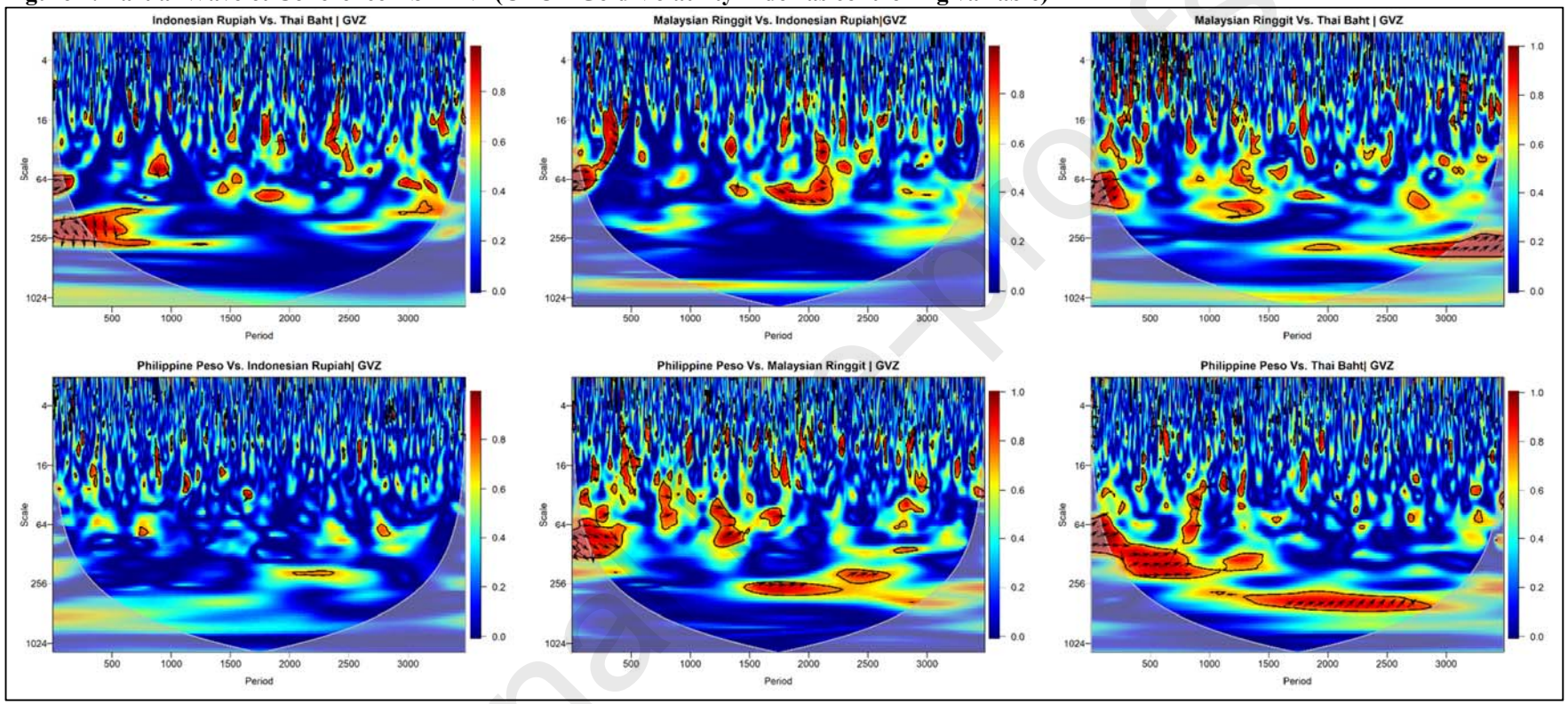
This figure applies partial wavelet coherence by using CBOE Gold Volatility Index as controlling variable to present the pairwise co-movement of currencies from SAARC5 countries namely Bangladeshi Taka, Indian Rupee, Sri Lankan Rupee, Maldivian Rufiyaa and Pakistani Rupee

Figure 3: Partial Wavelet Coherence ASEAN4 (CBOE Crude Oil Volatility Index as controlling variable)



This figure applies partial wavelet coherence by using CBOE Crude Oil Volatility Index as controlling variable to present the pairwise co-movement of currencies from ASEAN4 countries namely Indonesian Rupiah, Malaysian Ringgit, Philippine Peso and Thai Baht.

Figure 4: Partial Wavelet Coherence ASEAN4 (CBOE Gold Volatility Index as controlling variable)



This figure applies partial wavelet coherence by using CBOE Gold Volatility Index as controlling variable to present the pairwise co-movement of currencies from ASEAN4 countries namely Indonesian Rupiah, Malaysian Ringgit, Philippine Peso and Thai Baht.

Does the regional proximity lead to exchange rate spillover?

Zaheer Anwer was involved in conceptualization, made the estimations using software, wrote methodology section and interpretations.

Ashraf Khan performed the bibliometric review.

M. Kabir Hassan is corresponding author and performed the overall supervision of the project.

Mamunur Rashid prepared the introduction section.

Does the regional proximity lead to exchange rate spillover?

Highlights

- We explore dynamic co-movement of currencies from SAARC5 and ASEAN4 regions.
- Our results reveal very little co-movement between member currencies of both the regions.
- The regional proximity does not necessarily translate in exchange rate connectedness.

Does the regional proximity lead to exchange rate spillover?

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