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Article

Time-frequency nexus between remittances, exchange rates, and growth in Vietnam

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Abstract: The significance of remittances to the Vietnamese economy necessitates investigating how they affect the value of the Vietnamese currency and other macroeconomic factors. Macroeconomic articles struggle to discover their impact on economic development, but measured remittances by migrant workers have recently soared. There is no academic study that has examined this phenomenon in Vietnam. This study uses wavelet frameworks to analyze the lead-lag nexus between exchange rates, remittances, and economic growth in Vietnam in time-frequency domains from 1995 to 2020. Overall, we find that: (i) remittances enhance economic growth in the short and medium run; (ii) exchange rates boost remittances in the short and medium run; (iii) exchange rates promote GDP in all frequency and time domains. Moreover, the partial wavelet coherence and multiple wavelet coherence frameworks also offered evidence supporting the wavelet coherence approach. More importantly, the outcomes of wavelet-based Granger causality unveil that there is two-way causality between the selected indicators, which means that all the indicators can predict each other at different frequencies. Our empirical results provide meaningful information for market participants and policymakers.

Keywords: exchange rates; remittances; economic growth; wavelet analysis; Vietnam
JEL Classifications: F31; C32; E31

1. Introduction

Although remittances have benefited the countries that receive them in several ways, including reducing Inequality and poverty and improving financial development and human capital, they have also had some negative effects (Acosta et al., 2009; Khan et al., 2021; Awad and Sirag, 2018). In remittance-receiving countries, remittances may reduce labour supply, worsen governance and institutions, and strengthen exchange rates, thereby weakening the commercial portion of the economy (Olayungbo and Quadri, 2019). In addition, remittances are a valuable and consistent source of foreign funding and capital accumulation. As per Ale et al. (2018), remittances boost national savings, ease the balance of payments and foreign exchange restrictions, and support the development budget. It may hinder GDP through exchange rate appreciation, reducing international competitiveness. The focus of this study is to shed light on the time-frequency relationships between exchange rates, remittances and economic growth in Vietnam from 1995 to 2020.

In Vietnam, remittances play a vital role as a source of income for households and are regarded as a stable source (Hoang et al., 2020). In 2020, Vietnam was the third largest remittance-receiving country in East Asia and the Pacific Region (World Bank, 2020). Remittances to Vietnam, as a result, totalled $15.7 billion (equivalent to

5.8 per cent of Vietnam's total GDP) (World Bank, 2020). To put it another way, remittance inflow has increased along with economic expansion, and it is important to investigate the connection between them. However, following the global financial crisis of 2008 and 2009, the lowest growth rate of remittances was noted in 2015. The main causes of the reduced remittance growth rate in 2015 have been determined to be challenging economic conditions in the major remittance-source nations. The neoclassical migration hypothesis states that wage differences across nations are the cause of labor movement from low-pay countries to those with comparatively high wages. Remittances from immigrants help with economic growth and the fight against poverty in their home nations. Furthermore, the effect of real exchange rate variations on growth has been a major concern for Vietnamese economists and policymakers. There has been considerable discussion regarding the impact of remittances and exchange rates on GDP dynamics in time-frequency spaces. Understanding these issues could have significant implications for economic policymaking. Therefore, we concentrate on the remittances-exchange rates-growth nexus at different times and frequencies that impact macroeconomic fluctuations in a small, open, oil-exporting economy like Vietnam.

There is currently no strong evidence that remittances and exchange rates positively impact output, contrary to previous research on the subject. Some studies suggest that remittances significantly contribute to economic development (Păunică et al., 2019; Azizi, 2020; Stojanov et al. 2019; Abduvaliev and Bustillo, 2020), while others suggest a negative association between remittances and GDP (Awad and Sirag, 2018; Sutradhar, 2020; Jongwanich and Kohpaiboon, 2019). Specifically, other researchers have found that there is a bidirectional link between exchange rates and economic growth (Sekmen, 2007; Aliyu, 2009; Grossmann et al., 2016), and exchange rates have weak and negative relationships with economic development (Zumaquero and Sosvilla-Rivero, 2016; Comunale, 2017; Mrabet and Alsamara, 2018; Mao Takongmo and Lebihan, 2021). For Vietnam, using the VAR framework, Hoang et al. (2020) uncovered a significant influence of exchange rates on GDP between 2005 and 2018. Given the diversity of empirical findings, there does not seem to be a strong agreement between research studies on this topic, and the question of the interplay between remittances, exchange rates, and GDP in developing nations, particularly in Vietnam, remains unanswered. Additional research is needed due to the mixed and contradictory results of empirical studies. Put it in another way, there are no studies examining the time-frequency relationship between remittances, exchange rates, and economic growth in Vietnam. As a result, this study aims to fill this gap in the existing literature by presenting new empirical evidence regarding the Vietnamese economy. In these circumstances, we can offer the following research question: how are the remittances, exchange rates and GDP nexus in time and frequency spaces?

As mentioned, the current work makes some contributions. First, this article empirically investigates the short-medium-long-term intercorrelations between remittances, exchange rates, and economic growth in Vietnam. More importantly, particular focus will be placed on how exchange rates and remittances affect this nation's economic development. Vietnam was chosen as a case study because it is one of the two largest recipients of remittances, and this country has not been studied on multiple fronts on the remittances-exchange rates-growth nexus over different time

horizons. The analysis is critical because differences in how they affect GDP can make it hard to see how remittances and the consumption–investment ratio are being used. Second, based on the new methodology, this study looks into the multi-scale lead-lag relationship between changes in remittances, exchange rates, and economic growth. This technique utilizes wavelet coherency (WTC) and partial wavelet coherency (PWC), wavelet-based Granger causality (WG) developed by Olayeni (2016), and multiple wavelet coherency to decompose the time-frequency effects of changes in remittances and exchange rates on economic growth over the period 1995–2020 for Vietnam. Previous works that have studied these interactions utilizing time-domain econometric models such as ARDL, VAR, Granger causality, VECM, OLS, and DOLS, to the best of our knowledge, have not been published. Hence, the present study fills the gaps in prior articles by applying the wavelet approaches, which perfectly capture the lead-lag relationship at different times and frequencies. The wavelet method also permits more dependable monitoring of shocks that trigger changes in the flow of the business cycle (Mutascu and Sokic, 2022). This information has significant policy implications for encouraging long-term growth in Vietnam by developing and implementing sound economic development and exchange rate strategies.

The outline of this article is structured as follows. Section 2 represents related literature. Data and methodology are presented in Section 3. The empirical results are reported and discussed in Section 4. Section 5 concludes.

2. Literature review

This section of the current study looks at the studies that have been done on the connections between exchange rates, remittances, and economic growth.

2.1. Nexus between GDP and exchange rates

The literature is unanimous regarding the effect of exchange rate stability on economic growth. Sekmen (2007) and Schnabl (2007) argued that, from a macroeconomic standpoint, flexible exchange rates facilitate a more effortless adjustment to real asymmetric shocks specific to individual nations. In a fixed exchange rate regime, low exchange rate volatility is associated with lower transaction costs for international commerce and capital flows, enabling higher economic development (Aliyu, 2009; Hanslin Grossmann et al., 2016 Chintamani and Kulkarni, 2023). Indirectly, Fixed exchange rates improve international pricing transparency by allowing consumers to compare prices across countries more easily (Lebihan, 2021). Global arbitrage contributes to greater levels of efficiency, productivity, and welfare when fluctuations in exchange rates are eliminated. Previously, according to Mundell (1973a, 1973b), In small open economies, monetary and exchange rate policies are the main causes of unpredictability and volatility, whereas changes in exchange rates spur economic growth.

Empirical evidence has been demonstrated to show the short- and long-term negative effects of exchange rate fluctuations on economic growth performance via the trade channel. Kyereme (1991) studies the time-varying associations between the currency exchange rate and real output growth in Ghana and suggests a remarkable

nexus between these indicators. Sekmen (2007) investigates the causal impacts of the foreign exchanges and GDP in Turkey and finds a bidirectional relationship between these variables. Similarly, Aliyu (2009) uncovers two-way causality between the real exchange rate to GDP in Nigeria. Carrera and Vergara (2012) reveal that a devaluation of local currency has the potential to drastically change the course of a sustainable fiscal policy, as well as affect economic growth and interest rates.

Hanslin Grossmann et al. (2016) show that in Switzerland, there are notable differences in the international demand and exchange rate elasticity of export industries and export destinations. Morales-Zumaquero and Sosvilla-Rivero (2016) conclude that exchange-rate policies are crucial for both upper-class and lower-class nations, and that financial crises, irrespective of a nation's wealth level, have a substantial and adverse effect on GDP. Comunale (2017) investigates the influence of the exchange rates on economic growth in the EU during the boom and crisis period. They document that real exchange rates have been a further cause of the decline in GDP in the long run. Mrabet and Alsamara (2018) demonstrate that three major factors can explain the real GDP: exchange rates on the parallel market, money supply, and oil exports. Jovic et al. (2019) investigate the influence of exchange rates on GDP using an adaptive neuro-fuzzy inference system and confirm that exchange rate values can be used to forecast GDP. Hussain et al. (2019) examine the asymmetric effect of exchange rate changes on GDP in Pakistan and conclude that a weak currency reduces GDP while a strong currency increases it. In a similar fashion, Mao Takongmo and Lebihan (2021) demonstrate that the causal relationship between government spending and GDP is more significant and consistent in the United States when the exchange rate is disregarded.

Many papers have studied the impacts of exchange rate variations on economic development, mainly within developing economies, which are usually net oil importers. For example, according to Polbin et al. (2020), the Balassa-Samuelson shocks are mostly responsible for real exchange rate fluctuations, which also have an impact on Russia's real GDP dynamics. Hoang et al. (2020) examine the influence of foreign exchanges on GDP in Vietnam from 2005–2018 and provide evidence that exchange rates impact exports, imports, money supply, output, and prices in the economy. In Mauritius, Babubudjnauth and Seetanah (2021) suggest that local currency depreciation has an expansionary impact on the growth of manufacturing output in the short run but a contractionary effect in the long run. The following hypothesis is formulated:

H1: There is a bidirectional association between exchange rates and GDP in Vietnam.

2.2. Nexus between remittances and exchange rates

The literature on the interplay between GDP and remittances is extensive, whereas the literature on the nexus between remittances and the exchange rate is scant (Kuncoro, 2020). Two strands of economic literature link exchange rates and remittances. The first channel is dependent on how remittances affect exchange rates; remittances give rise to exchange rate hypotheses (Essayyad et al., 2018; Dutta and Sengupta, 2018). How is the universally acknowledged fact that a rise in remittances

causes a better balance of payments by significantly narrowing the deficit in the current account and then spurring GDP growth? Changes in supply of foreign currency eventually have an impact on exchange rate growth (Khan et al., 2021; Kuncoro, 2020).

The second channel operates in the opposite direction, with exchange rates serving as a precursor to hypotheses about remittances. The neoclassical theory states that remittance flows are influenced by consumer income, the cost of goods and services in the destination country relative to those in the host country, the cost of transportation, the distance from the destination and the neighbouring country (Kuncoro, 2020; Acosta et al., 2009; Essayyad et al., 2018; Azizi, 2021).

Numerous articles have examined the effects of remittances on the real exchange rates of a single country. The following are descriptions of a few of these papers. According to Essayyad et al. (2018), growing remittance inflows cause Nepal's currency to appreciate over the long term while depreciating over the short term. In a similar fashion, Dutta and Sengupta (2018) use the ARDL model to estimate the long-term nexus between remittances and exchange rates in India and provide evidence of significant long-run relationships between these indicators. Kuncoro (2020) documents that exchange rates and remittances are co-integrated and bidirectional causality and that both in the short run and the long run, remittance inflows have a pro-cyclical effect on the Indonesian economy. Mohammed and Ahmed (2021) suggest that in Ethiopia, economic growth and inflation had a negative impact on the exchange rate, while economic growth had a negative impact on remittances. Khan et al. (2021) demonstrate that remittance inflow and trade balance have a statistically significant positive impact on Bangladesh's foreign exchange reserves over the long term. Similarly, Joof and Touray (2021) reveal that remittances have a large beneficial impact on The Gambia's actual effective exchange rate.

The effects of remittances on exchange rates in a group of countries have been the subject of some studies. For example, Acosta et al. (2009) utilize panel data from 1990 to 2003 for 109 developing and transition countries. The findings indicate that remittances exert upward pressure on the real exchange rate. To estimate the possible impact of the COVID-19 pandemic, Awode et al. (2021) investigate the links between remittances, remittance volatility, and macroeconomic performance in seven African nations. The authors find that while remittances themselves have a positive and considerable impact on GDP, consumption, and investment in this region, remittance volatility has a negative but negligible influence on exports, exchange rates, and GDP. Azizi (2021) uses data from 101 developing countries between 1990 and 2015 to examine how remittances affect net exports and real exchange rates. He finds that in countries that receive remittances, real exchange rates rise while net exports fall. The following hypothesis is formulated:

H2: There exists a bidirectional relationship between exchange rates and remittances in Vietnam.

2.3. Nexus between GDP and remittances

From the perspective of national income accounting, Remittances enter the economy through the current account. As a result, these remittances are now available for investment and consumption. The importance of remittance flows in generating

and sustaining rapid economic growth in developing countries has been debated in the literature on development economics. Remittances have an impact on economic activity via multiple intermediary channels (Das et al., 2019; Comes et al., 2018). Remittances have the potential to improve well-being through increasing investments, consumption, human development, and education. They can also reduce poverty and ease financial restrictions. Also, remittances help spread technology, which is good for the growth of developing countries (Ale et al., 2018; Ale et al., 2018; Sutradhar, 2022) and improves the quality of democratic institutions in those countries.

Regarding the correlation between GDP and remittances, Awad and Sirag (2018) examine the persistence of the Dutch disease hypothesis by looking at the remittance-growth nexus for Sudan. They argue that a variety of mechanisms, including currency rate depreciation rather than appreciation, could cause remittances to have a negative impact on economic growth. As per Rausser et al. (2018), remittances from migrants have a major and beneficial impact on the economic growth of Lithuania, Latvia, and Estonia. Mehedintu et al. (2019) conclude that despite a dropping value trend, remittances have been and will remain a relatively steady financial resource for Romania and other emerging nations in Europe, positively impacting the standard of living of the populace.

After analyzing the link between remittances and GDP in Jamaica from 1976 to 2014, Das et al. (2019) come to the conclusion that the two variables are positively reinforcing of one another and have a cointegrated relationship. Comes et al. (2018) find that FDI and remittances positively impact GDP. Similarly, Păunică et al. (2019) report that remittances have a positive effect on GDP only in Italy, the Czech Republic, Germany, and Greece. Olayungbo and Quadri (2019) reveal that remittances and financial development have positive short- and long-term effects on economic growth. Azizi (2020) demonstrates that remittances boost financial development in developing countries, which promotes long-term growth and reduces poverty.

There is conflicting empirical evidence regarding the interplay between remittances and economic growth. Ale et al. (2018) found a substantial bi-directional relationship between economic development and remittances in India, but a one-way causal relationship between remittances and economic growth in Bangladesh. Kumar et al. (2018) support the findings of Ale et al. (2018) and document that remittances have threshold impacts on growth in Bangladesh and India. Stojanov et al. (2019) note that *t* the inflow of remittances was more constant than the inflow of aid, and development aid did not contribute to long-term economic growth between 1970 and 2017. Abduvaliev and Bustillo (2020) evaluate the impact of remittances on economic development amongst the post-Soviet states and report that, on average, a 1% increase in remittance flows causes a 0.25 percentage point increase in per capita GDP. Bajra (2021) looks at how migrant remittances affect economic growth and inequality in the Western Balkans as a whole. while remittances have an effect on economic growth, he believes they also stimulate a high degree of migration and use up a large number of workers by altering the labor market and making it easier for people to migrate without control. Sutradhar (2020) looks into the effect of remittances on the growth of emerging South Asian nations. Their findings confirm that remittances have a negative impact on the economies of Bangladesh, Pakistan, and Sri Lanka, while they have a positive effect in India. The impact of remittances on economic development in

emerging Asia-Pacific nations is examined by Jongwanich and Kohpaiboon (2019), who find that remittances only significantly and negatively affect economic growth when they surpass 10% of GDP. The following hypothesis is formulated:

H3: Remittances contribute significantly to GDP in Vietnam.

2.4. Research gap in literature

According to the research reviewed above, previous studies have extensively focused on the causal relationship between GDP, remittances, and exchange rates, as well as how these remittances and exchange rates effect GDP in Vietnam. Furthermore, previous research has only looked at this relationship in the time domain in developing nations in general, and Vietnam in particular. As a result, by addressing this vacuum in the literature, this work attempts to contribute to the literature.

3. Methodology

Wavelet analysis is employed in this study, including continuous wavelets, wavelet coherence, partial and multiple wavelets to estimate how the local variance and covariance of two indicators make progress, and wavelet coherence and phase analysis to highlight the intercorrelation between time series in the time-frequency domain. In the time-frequency space, a localized correlation coefficient can be used to determine the wavelet coherency. It shows the time and frequency components, as well as the correlation strength, in a three-dimensional representation of the correlation between time series. The synchronizations and delays between variables are described by the phase-difference. Because the wavelet coherency value is positive, it is computed between lead-lag connections and positive and negative correlations. The model of the wavelet coherence framework can be concisely represented in this section, according to Torrence and Webster (1999). **Figure 1** shows modeling strategy.

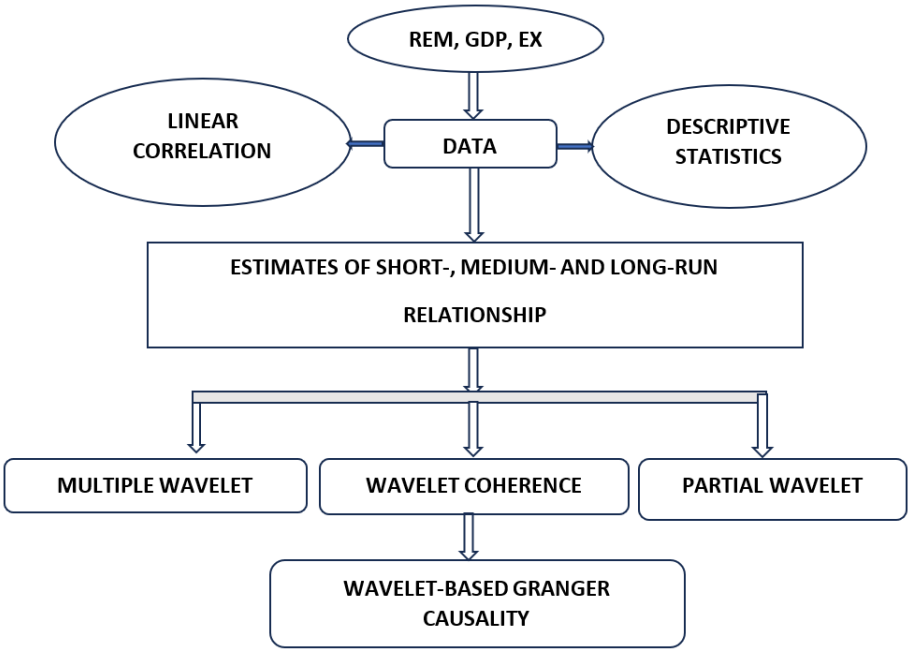

Figure 1. Modeling strategy.

3.1. Continuous wavelet transform

The wavelet transform is a type of continuous transform. The interaction of time series can be estimated using $W_x(s)$ for both frequency and time. The wavelet is calculated as follows:

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

where * represents whether the wavelet is capable of capturing higher or lower components of the series $x(t)$ is indicated by the complex conjugate and the scale parameter *s*, when the admissibility condition is satisfied. When $|W_X|^2$ is used to define the wavelet power spectrum, it implies that there is a strong correlation between the variance distribution of the different frequency components of the original time series and its temporal evolution.

3.2. Wavelet coherence

The localized intercorrelation can be effectively estimated by the wavelet coherence technique (WTC) through series in the time and frequency domains. The expression for the cross-wavelet of two series, $x(t)$ and $y(t)$, is as follows:

$$W_n^{XY}(u,s) = W_n^X(s,\tau) W_n^{Y*}(s,\tau) \quad (2)$$

where *u* stands for position and s for scale, and * denotes the complex conjugate. These steps can be used to calculate the WTC:

$$R_n^2(s,\tau) = \frac{|S(s^{-1} W_n^{XY}(s,\tau))|^2)}{S(s^{-1}|W_X(s,\tau)|^2) S(s^{-1}|W_Y(s,\tau)|^2)} \quad (3)$$

where *S* denotes a simultaneous process of time and frequency smoothing. $R_n^2(s,\tau)$ is in the range $0 \leq R^2(s,\tau) \leq 1$.

The following formula for the partial wavelet coherence tool allows us to compute the WTC between two series (*y*, *x*1) after accounting for the influence of a third series (*x*2):

$$RP^2(y, x_1, x_2) = \frac{|R(y,x_1) - R(y,x_2).R(y,x_1)|^{*2}}{[1 - R(y,x_2)]^2 [1 - R(x_1,x_2)]^2} \quad (4)$$

The ability to examine the coherence of multiple independent variables on a single dependent variable is a strength of the multiple wavelet coherence approach.

$$RM^2(y, x_2, x_1) = \frac{R^2(y,x_1) + R^2(y,x_2) - 2\,Re[\,R(y,x_1).R(y,x_2)^*.R(x_1,x_2)]}{1 - R^2(x_1,x_2)} \quad (5)$$

3.3. Causality in continuous wavelet transform

For Granger causality, Olayeni (2016) developed a continuous wavelet transform, which is applied in this investigation. One way to spell it is as

$$G_{Y \to X}(s,\tau) = \frac{\xi\{s^{-1}|\Re(W_{XY}^m(s,\tau)) I_{Y \to X}(s,\tau)|\}}{\xi\{s^{-1}\sqrt{|W_X^m(s,\tau)|^2}\}\xi\{s^{-1}\sqrt{|W_Y^m(s,\tau)|^2}\}} \quad (6)$$

where $W_Y^m(s,\tau)$, $W_X^m(s,\tau)$ and $W_{XY}^m(s,\tau)$ are the wavelet transformations and $I_{Y \to X}(s,\tau)$ as the indicator function which is written as

$$I_{Y \to X}(s,\tau) = \begin{cases} 1, if\, \phi_{XY}(s,\tau) \in (0, \pi/2) \cup (-\pi, -\pi/2) \\ 0, otherwise \end{cases} \quad (7)$$

3.4. Wavelet correlation

The developed wavelet cohesion, which is used for robustness testing, was introduced by Rua (2013). The correlation intensity measure is developed by $\rho_{x,y}$ as the real number on [-1, 1] by taking into account the wavelet cross spectrum:

$$\rho_{x,y} = \frac{\Re\left(W_n^x W_n^y\right)}{\sqrt{|W_n^x|^2 |W_n^y|}} \tag{8}$$

3.5. Data

We evaluate the time-frequency nexus between remittances, exchange rates, and economic growth in Vietnam. The study uses annual frequency data spanning the period 1995–2020 for Vietnam. The indicators used in the empirical analysis are economic growth, remittances, and exchange rates. All data is sourced from the World Development Indicator online database. These indicators are utilized in the majority of past studies. For the empirical analysis, the yearly series are then transformed into monthly data utilizing a quadratic match-sum technique, which makes adjustments for fluctuations in the series when converting from low frequency into high frequency by reducing the point-to-point data variations (Hung, 2022). This technique is advantageous because of its convenient operating procedure compared to other interpolation approaches (Arain et al. 2020). Finally, all related indicators are transformed into different logarithmic series to produce comparable empirical results.

Table 1 shows a snapshot of descriptive statistics for exchange rates (EX), remittances (REM), and economic growth (GDP) in Vietnam over the sample period. The average values for EX and GDP are positive, while the figure for REM is negative. By contrast, the standard deviation coefficients indicate that GDP fluctuated dramatically in Vietnam (0.696), followed by the REM and EX, respectively. The Jarque-Berea test for normality confirms that none of the variables is normally distributed. Based on these statistics, it is helpful to look into the interaction between GDP, EX, and REM in a time-frequency domain.

Table 1. Descriptive statistics of the examined variables.

Variables	Mean	Minimum	Maximum	Std. Dev	Jarque-Bera
EX	7.347679	7.056498	7.602967	0.181001	31.66448***
GDP	4.648108	3.363889	5.753901	0.759554	21.51552***
REM	−0.732590	−1.312172	−0.384668	0.201961	50.49807***

*** presents the values are significant at 1%.

Figure 2 shows the pairwise correlation between the remaining variables. We can observe that unconditional correlation, in general, is significantly high between selected pairs. Specifically, the highest correlation of 97% can be seen between GDP and EX, while the magnitude of the correlation is significantly lower between EX and REM.

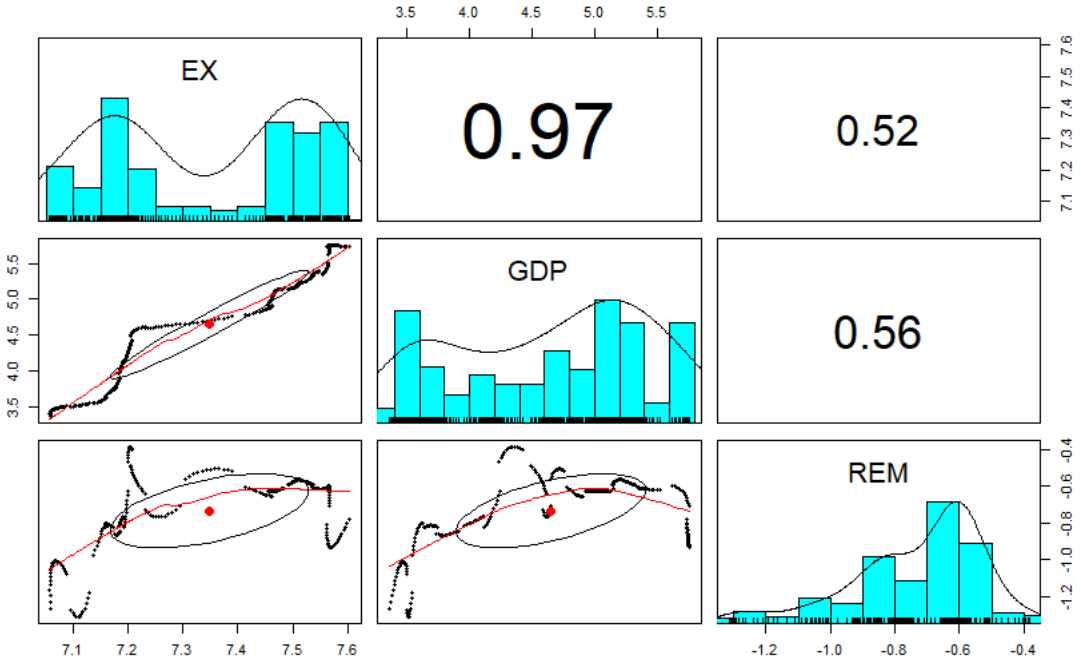

Figure 2. Plots of distribution and the pair-wise correlations of the variables.

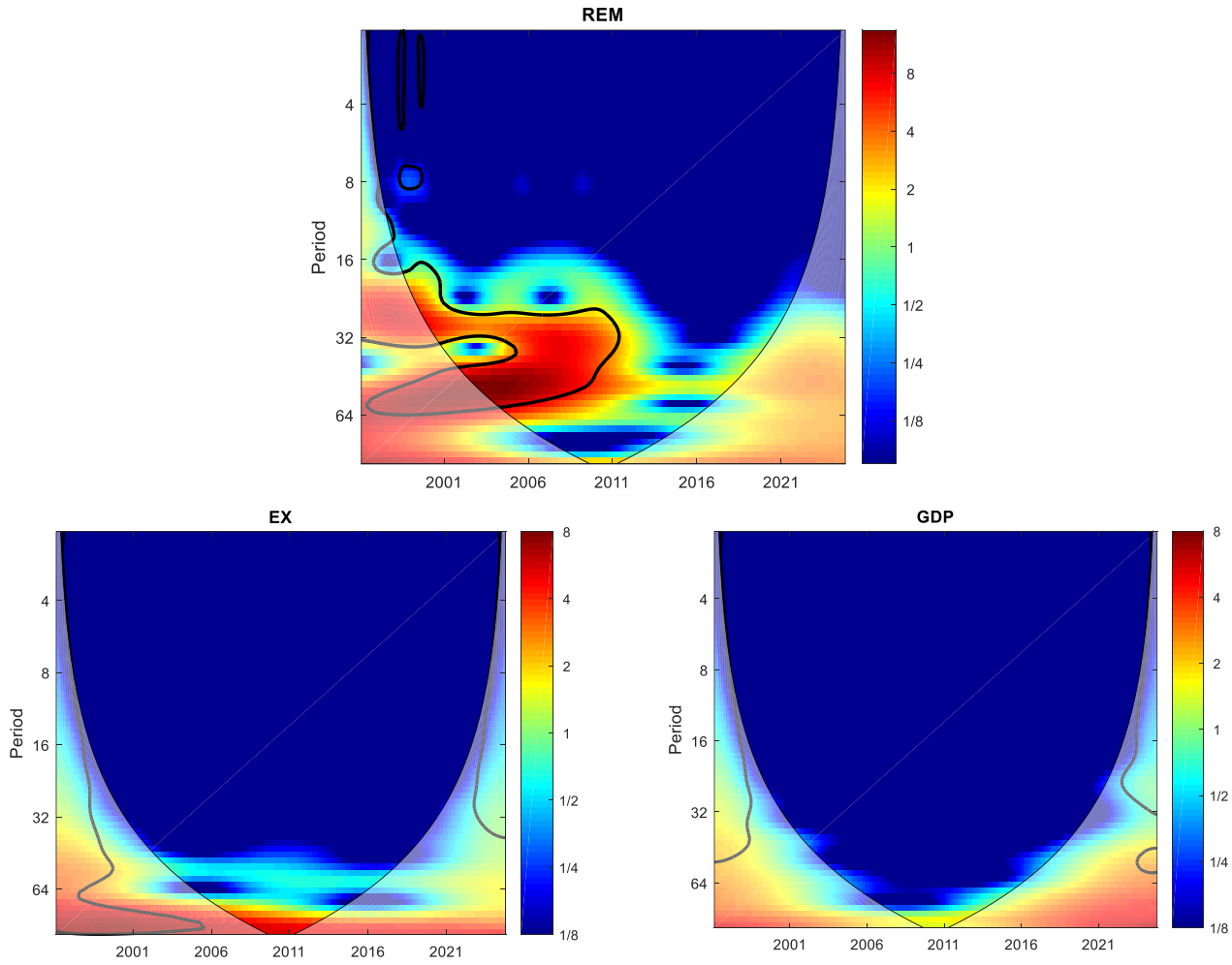

Figure 3. Continuous wavelet power spectrum for GDP, EX, and REM.

Figure 3 depicts the wavelet spectra of the GDP, EX, and REM series. A counterplot is used to describe the power spectrum. The colour ranges from blue to red, indicating low to high levels of local variance power. The thick black contour depicts the wavelet power spectrum's significance level of 5% against red noise. Individual wavelet spectra, in general, allow us to visualize the index's local variance in frequency-time space. We can see from these plots that all of the selected time series have low local variance levels, except REM, which is indicated by the red area from 2000 to 2010.

4. Results

We start our investigation by examining the wavelet coherence and phase-difference results for remittances, GDP, and exchange rates that are displayed in **Figure 4**.

The coherency, which goes from red (high coherency) to blue (low coherency), indicates the degree of co-movement. A red color show strong relationship, whereas a blue color suggests weak association. In addition, we discern causality and phase differences by arrow dimensions. For instance, → and ← represent that the indicators are in phase and out of phase, respectively. Being in phase shows a positive interdependence while out of phase indicates a negative correlation between respective indicators. More so, ↗ and ↙ suggest that the first variable is leading the second one, while ↘ and ↖ show the first indicator is lagging those of the second one.

Figure 4 describes the wavelet coherence (WTC) and cross wavelet transform (XWT) for GDP, REM, and EX indicators. First, we observe on the left-hand side of Figure 4, and it is interesting to note that the direction of the arrows at various scales and periods is totally different between the pairs of the concerning indicators. It is clear that the pairs of REM-GDP, GDP-EX, and EX-REM in Vietnam display a zone of strong coherency and co-movement at the lower frequencies between 2005 and 2015. In addition, we note that the arrows towards the right up and left down, which represent REM, GDP, and EX, are leading at different times and frequencies. However, this approach cannot be attributed to the lead-lag nexus between the two series. As a result, we reformulated the analysis using wavelet coherence, which allows us to determine remarkable interactions between two series in both time and frequency bands. We plot the findings of WTC on the right-hand side of **Figure 4**.

The coherency plots uncover a generally low to strong relationship between the selected pairs, as the mass of the significant red contours decreases along time scales, especially from the very long scale horizons. For the cases of REM-GDP and EX-REM, there exist strong relationships at the high to medium frequencies during the period shown. However, these linkages are significantly lower at the low frequency and also stretched across the historical time interval. Similarly, the degree of intercorrelation between GDP and EX is strong between 4- and 32-months scales for the entire sample period. More importantly, the phase pattern between EX and GDP suggests the persistence of a negative nexus. The arrows, in anti-phase, show that there is a negative relationship between EX and GDP in the short and medium time scales. In contrast, exchange rates have a positive impact on GDP in the long run. The reason might be that an increase in EX fluctuation causes an increase in GDP in this country.

The exchange rates and vice versa significantly influence economic growth. Changes in exchange rates influence changes in aggregate demand and monetary factors, which influence GDP. These findings are consistent with the studies of Hanslin Grossmann et al. (2016), Jovic et al. (2019), Hussain et al. (2019) and Mao Takongmo and Lebihan (2021), who reported the persistence of a considerable nexus between GDP and exchange rate. This implies that GDP can be spurred up through deliberate manipulation of the domestic currency.

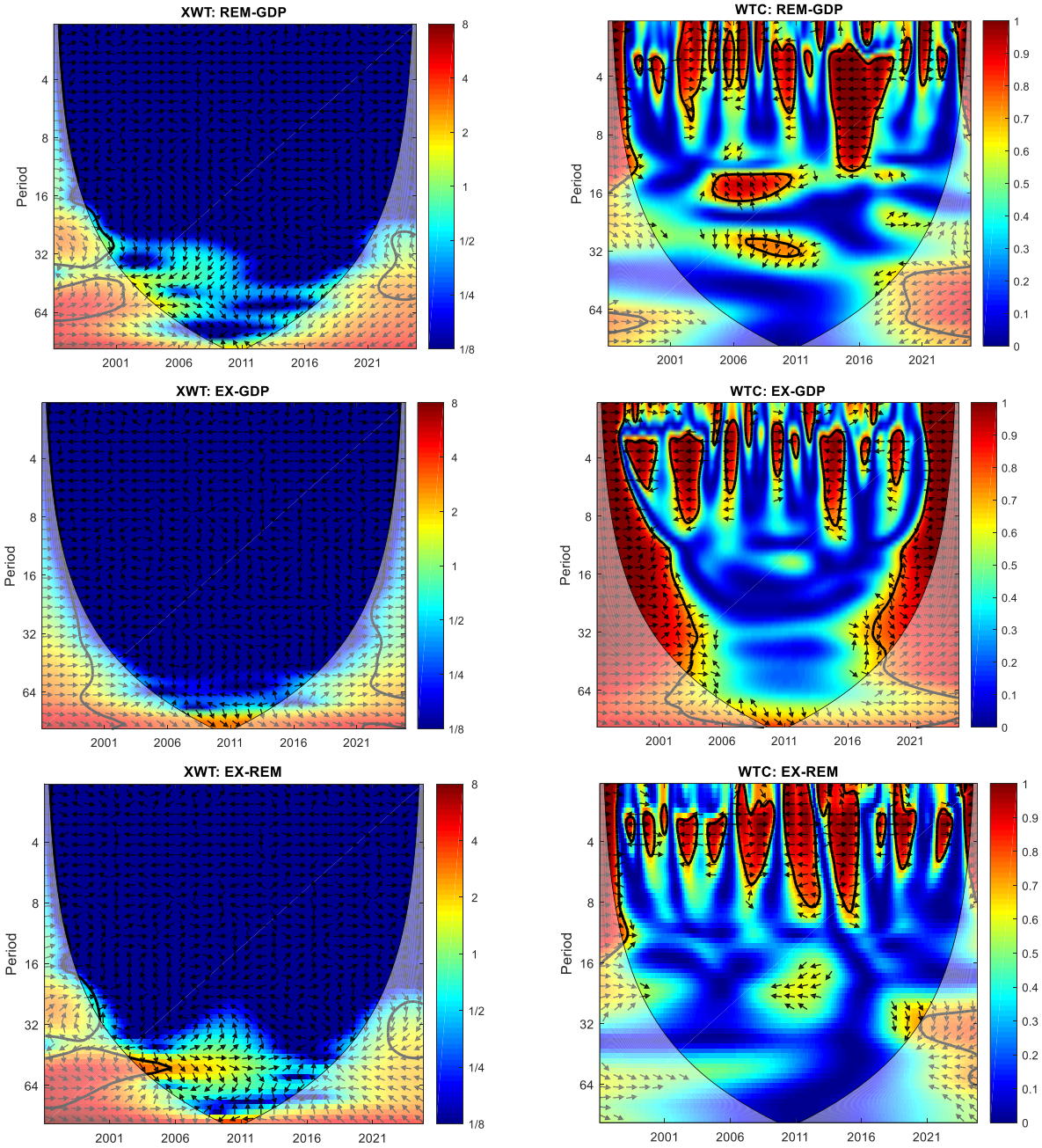

Figure 4. Cross wavelet transform power spectrum (left side) and wavelet coherence (right side) between GDP, EX and REM.

Specifically, remittances positively impact economic growth in the medium run from 2019 to 2020, which suggests that remittances have been effectively utilized in recent years in Vietnam. On the other hand, we note that there was a negative

association between remittances and GDP from 1990 to 2018. This means that the relevance of remittances in the growth process is decreasing, as evidenced by the past, maybe because remittances are utilized increasingly for consumption, and growing output is mostly supported by industries unrelated to remittances. Put differently, remittances help Vietnam by boosting domestic consumption and lowering poverty. Remittances may increase the poor's income level and contribute to the reduction of poverty. Therefore, remittances are more advantageous for reducing poverty than promoting economic growth (Sutradhar, 2020). As a result, the findings suggest that remittances in Vietnam do not have a direct growth-boosting impact, which is in line with the findings of Kumar et al. (2018), Rausser et al. (2018), Das et al. (2019), Olayungbo and Quadri (2019) and Azizi (2020).

Similarly, in the nexus between REM, GDP, and EX, the arrows point left and up, which implies an out-of-phase co-movement, with REM leading. The findings can be explained as follows: When two indicators are out of phase, they co-move in opposite directions. Put differently, there are negative relationships between REM and GDP and REM and EX in the short and medium time scales over the research period. One possible explanation is that Vietnam still adheres to the managed float and that the crowding-out effect prevents monetary policy from being effective. The GDP is impacted negatively by interest rates. As usual, inflationary shocks lower GDP by lowering consumer and business confidence, raising nominal interest rates, and decreasing the amount of money that can be borrowed from within the country.

In addition, the nature of the nexus between exchange rates and remittances cannot be identified a priori. This is due to the fact that remittance inflows have an indirect impact on currency rates through their impact on the household incomes of recipient families and whether or not those families decide to spend the money on goods and services rather than saving it. As a result, we can expect that the rise in REM will result in either currency appreciation or depreciation. These findings are in line with the analysis of Dutta and Sengupta (2018), Kuncoro (2020), Mohammed and Ahmed (2021), Khan et al. (2021), and Joof and Touray (2021), who report that the influence of remittances on exchange rates is statistically significant. Pant and Budha (2016) use a theoretical model and suggest that remittances cause currency appreciation, particularly when a nation has limited trade and capital openings.

4.1. Partial and multiple wavelet coherence results

Figure 5 depicts the partial wavelet coherence (PWC) and multiple wavelet coherence (MWC) between GDP, REM, and EX indicators at different time and frequency domains. Based upon this two-dimensional cone of influence plots, the region depicted in red demonstrates the strongest interdependence. In contrast, the area characterised in blue shows no correlation or a weak correlation. The graphs clearly show how indicators at different time scales relate to one another.

To begin with, we observe in the case of EX-GDP that the PWC between EX and GDP after cancelling out REM, while the other is the MWC between EX and GDP with REM. The findings suggest that EX and GDP have a dramatic interaction in the short, medium and long run, with the REM influence excluded. The MWC exhibits an entirely different situation for GDP and EX coherence when the impact of REM on

both these is undertaken. Strong relationships are observed in all frequencies over the period shown. Overall, the PWC and MWC affirm a strong and robust influence of REM in examining the relationship between EX and GDP in Vietnam. The findings are in line with the WTC, which validates the persistence of the lead-lag nexus between exchange rates and economic growth. Our findings tilt towards supporting the persistence of the bidirectional association between remittances, GDP, and exchange rates, which contradicts the results of Aliyu (2009) and Mao Takongmo and Lebihan (2021).

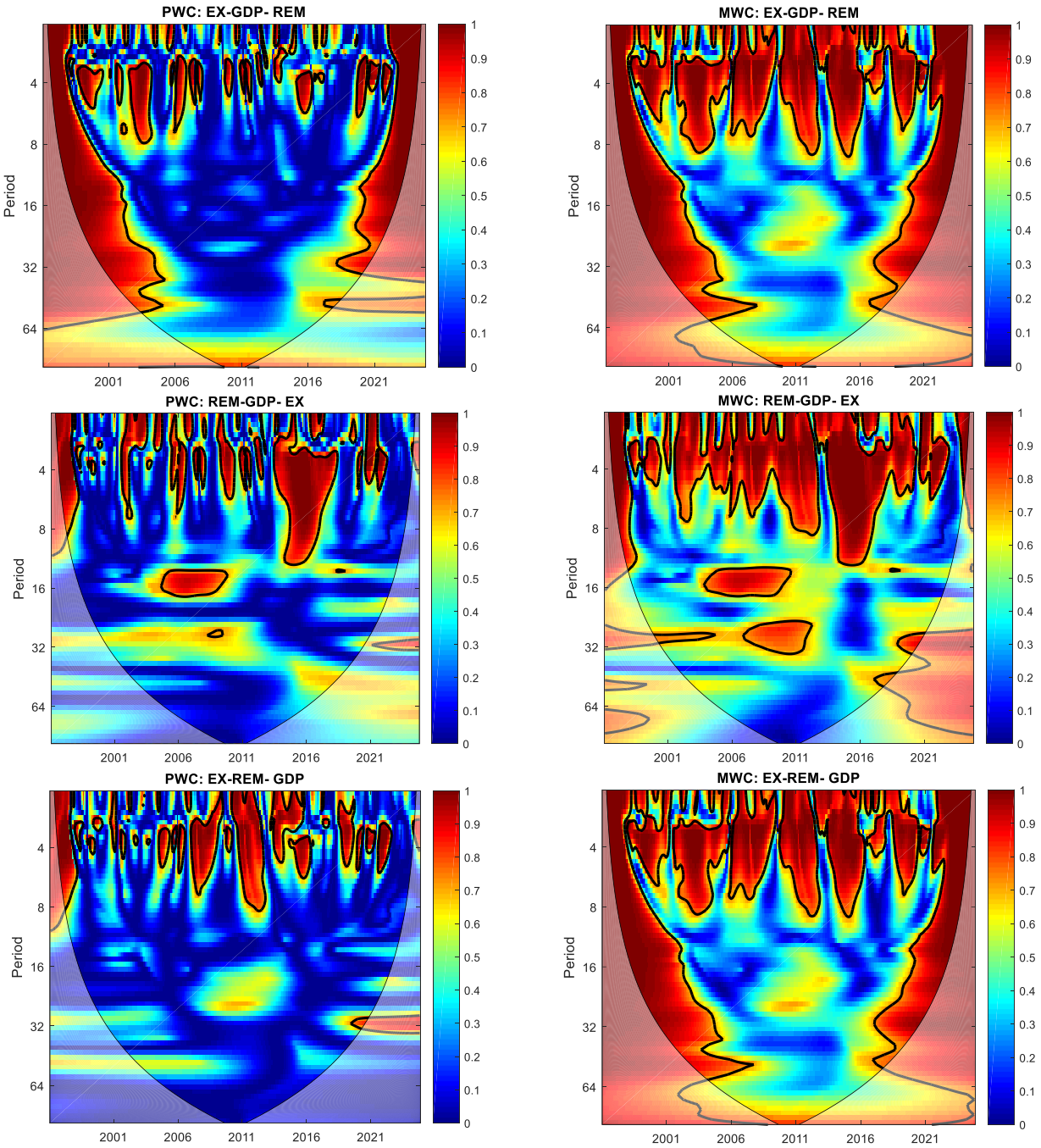

Figure 5. Results of partial and multiple wavelet coherence between CO2, GDP and GLO for Vietnam.

Next, we see the outcomes of the PWC between GDP and remittances later, removing the exchange rate influence. The correlation coefficient can be seen to be strong and significant areas are determined in the 0–16 months cycle (short and medium horizons) during the sample period. In addition, when observing EX in the relation between GDP and REM (MWC), there is a noticeable strong interaction in the short-to-medium phase, in which we can see the correlation coefficient ranges from 0.4 to 0.9. Nevertheless, in the long run, EX, REM, and GDP all co-move together quite well. The outcomes support the estimates of WTC that EX impacts GDP and remittances in the short-medium run, but there is no influence in the long run.

Figure 5 demonstrates the PWC between exchange rates and remittances, stopping GDP. The correlation coefficient is seen to be weak, and some red-coloured significant regions are observed in a 0–8 months cycle during 2005–2016. On the other hand, the multiple wavelet coherence for Vietnam from 1995 to 2020 is also represented in **Figure 5**. In the high and medium frequencies, there is coherence between EX and REM with GDP's effect over the period shown. In addition, in the long run, there is evidence of co-movement between EX and REM from 2005 to 2015. Overall, there is a robust coherence between EX, REM, and GDP in the short and medium run over the sample period. The outcomes tally with the earlier results (WTC) that GDP impacts exchange rates and remittances in the short and medium run.

4.2. Further analysis

Given the fact that the WTC does not assess how each indicator effects the other at different time horizons. Therefore, we employ the method of wavelet-based Granger causality developed by Olayeni (2016) to capture the causal effects between the examined variables. This approach enhances the examination of the degree of intercorrelation and the lead-lag nexus between indicators. **Figure 6** shows the findings of the wavelet-based Granger causality between the examined variables. The colour code shows the strength of the causal association between the two indicators (ranging from 0 to 1). The causal effect of GDP on EX is observed from 1995 to 2005 on 4–64 months and between 2015 and 2020 on an 8–16 month frequency, and this is a relatively lower causal effect. On the other hand, EX has a strong causal effect on GDP, which is found during the sample period on a 0–4 month frequency and between 2014 and 2020 on a 4–32 month frequency. For REM, the causal effect on EX is seen from 2017 to 2020 at short and medium frequencies. By contrast, we observe weak causal effects of EX on REM during the sample period from 4–16 months. In addition, weak causal effects between REM and GDP are also found at various time and frequency bands.

Overall, **Figure 6** clearly indicates the existence of significant causal connections between GDP, exchange rates, and remittances in Vietnam at short and medium frequencies during the entire sample period for the two possible directions of causality. A possible explanation for this outcome is that when the exchange rate increases (the primary real price of goods and services in an open economy), it impacts remittances and GDP in Vietnam. Theoretically, the likelihood of sending remittances to the country of origin increases with migration, but not by enough to have an impact on the welfare of the nation beyond raising the inequality threshold. The bulk of the

population often uses remittances for household expenses, which raises the possibility of harming the labour market owing to the habit of lethargy that is fostered and creates age dependency among the silent majority. Remittances may be too modest to be used for capital investment; hence, consumption will likely continue to be the primary end-use.

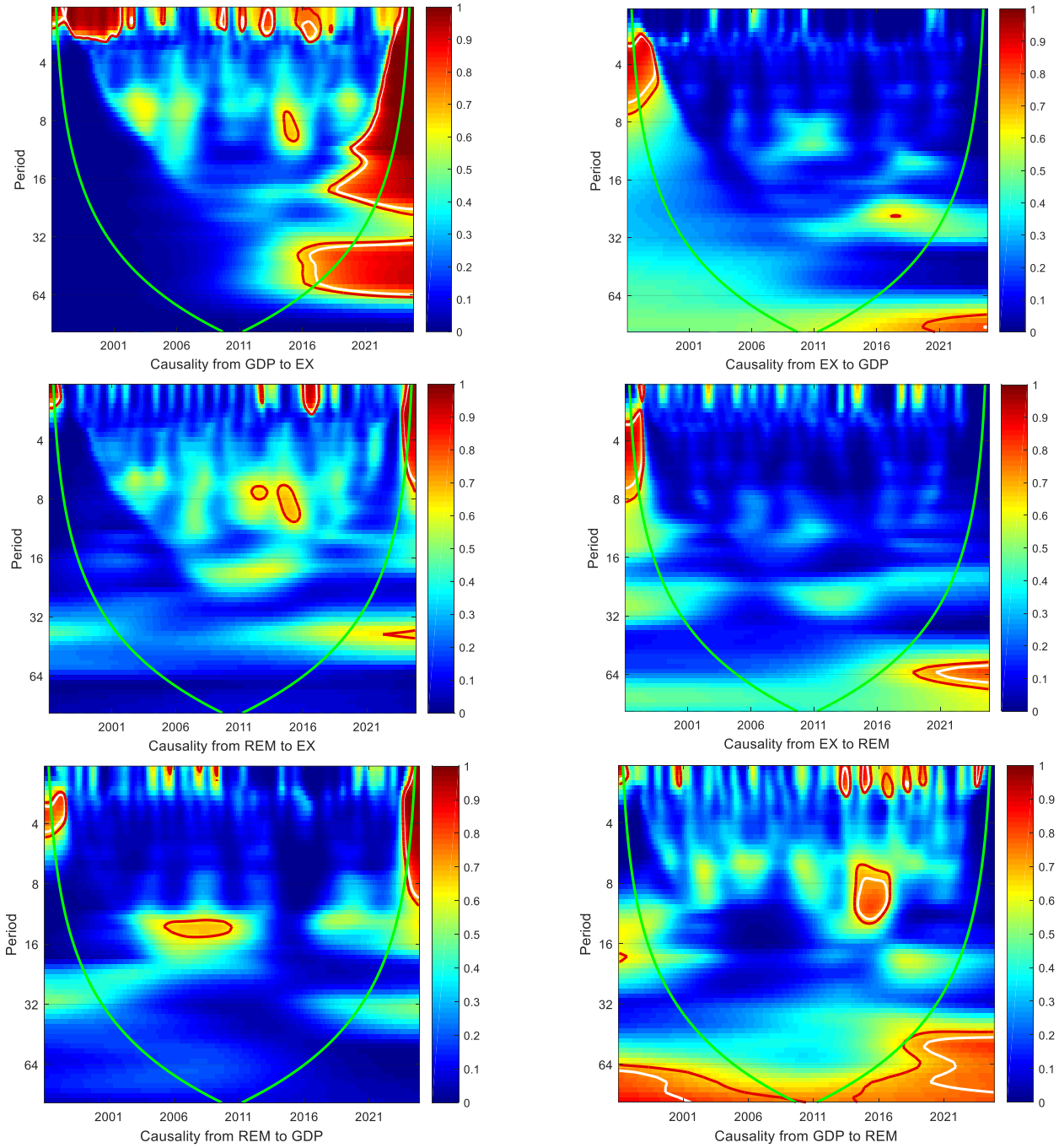

Figure 6. Wavelet-based causality between EX, GDP and REM in Vietnam.

5. Discussion

Our results suggest that remittance and exchange rates significantly influence GDP in the medium run. This is a vital conclusion because it uncovers that the role of remittances and exchange rate in the growth process would be ever present in the

taking economic policy decision of Vietnam as well as the exchange rate policy. These outcomes are in line with studies of Hanslin Grossmann et al. (2016), Jovic et al. (2019), Dutta and Sengupta (2018), Mohammed and Ahmed (2021), Rausser et al. (2018), Olayungbo and Quadri (2019), Kumar et al. (2018) and Jongwanich and Kohpaiboon (2019). Moreover, given the significant coherence existing between EX, REM and GDP, the decision in connection with the latter might have crucial consequences on the dynamics of the economic system. This analysis emphasizes the comparative safety of remittances over official foreign aid as a source of capital inflow into Vietnam. It is vital that monetary and fiscal policies in Vietnam improve the financial infrastructure that would permit the seamless entry of remittances as an alternative source of money into the country. In addition to using remittances for the domestic needs of recipient families, creative strategies should be implemented to unleash the economic potential of these inflows for investment in the local economy.

5.1. Policy insights

We have found quite an interesting result that in Vietnam, there is a bidirectional causation between exchange rates and remittances, which indicates that the more remittances that flow into the country, the higher the exchange rates. In other words, currencies are overvalued because remittances run into consumption and spending. At the same time, the extra remittances will come into an investment, resulting in a decrease in exchange rates for this nation, which receives a high ratio of remittances. Additionally, remittances are the result of a social process that develops gradually and is susceptible to abrupt halts or reversals. Remittances are becoming increasingly important in Vietnam's macroeconomic adjustment; thus, monetary and fiscal policy must be rethought. The result suggests that monetary and fiscal policies must work together to absorb the massive remittances to this country and reduce their negative effect on the real effective exchange rate. More so, monetary policy should aim to attain and maintain price stability, as well as to open the market for receiving remittances by increasing investment and human capital, ensuring inflation rate stability, and enhancing domestic production and export trade.

The findings indicate that remittances are relatively high in Vietnam and that A rise in the ratio will continue to boost economic growth. Obviously, Remittances must be used effectively, and the findings show that they contribute more directly to Vietnam's growth-enhancing process than previously thought. Nevertheless, remittances have negative effects on GDP, which suggests that remittances do not contribute significantly to economic growth. Remittances thus have a more indirect and intermediary function in the process of economic growth. We underline that, even if the absolute volume of remittances rises, a strong flow of remittances will help GDP growth if the ratio is balanced and remittances are used properly.

Our empirical analysis suggests that when exchange rates become more stable, as a developing nation, Vietnam is likely to experience faster economic growth in the coming years. Given the overall negative effect, the policy implications for a nation like Vietnam aimed to reduce currency volatility and integrate parallel and official markets. This is because a stable exchange rate regime positively affects economic growth over the long term. In spite of evidence supporting the negative influence of

exchange rates on growth, it is demonstrated that a flexible exchange rate reduces the probability of a crisis in the near future. Therefore, we can conclude that Vietnam's monetary policy would aim to lessen exchange rate fluctuations in order to boost economic development and decrease economic ambiguity.

Moreover, a fall in the real domestic currency stimulates growth and improves the deteriorating goods trade balance. Nevertheless, it can deplete international reserves and generate inflationary pressure over time. The bank of Vietnam must balance its developmental goals and price stability in light of its obligation to maintain higher reserves to avoid offshore sector vulnerabilities. As a result of the government's recognition of the importance of investment to economic expansion, the National Economic Development Board was established to encourage private investment.

6. Conclusion

Using the monthly data from 1995 to 2020, this article investigates the interplay between the exchange rate, remittances and economic growth in Vietnam in time-frequency domains. We employ methodologies of biwavelet and partial wavelet coherence to capture lead-lag interactions. Additional support for the claims presented in the study is now provided by this paper, which incorporates wavelet-based Granger causality to determine the strength and direction of causal effects over time and across different frequencies simultaneously. The empirical literature intensively examines the particular subject of the remittances-growth relationship because of the number of intercorrelations that can arise between exchange rate changes and monetary policy. Additionally, Vietnam has become one of the major remittance recipients; this shows a significant case study for analyzing this association.

Comprehensive information on this dependency is supplied for various frequencies and subperiods, illustrating the lead-lag nexus between the selected variables under cyclical and anti-cyclical influences. The WTC findings uncover that: (i) REM enhances economic growth in the short and medium run; (ii) EX boosts REM in the short and medium run; (iii) EX enhances GDP in all frequency and time domains. Moreover, the PWC and MWC frameworks also offered evidence supporting the WTC approach. More importantly, the findings of wavelet-based Granger causality unveil that there is bidirectional causality between the examined indicators, which means that all the indicators can predict each other at different frequencies.

Our findings suggest that remittances and exchange rates provide an explanation for how the Vietnamese economy has grown economically. Therefore, the government and policymakers should pay close attention to the trends of each of these indicators, advocating for policies that will broaden the remittance regime in line with other macroeconomic variables and increase economic growth. More so, our conclusion implies that the role of remittances in the growth process may be ever present in the taking economic policy decisions of Vietnam. This also applies to the exchange rate policy. In reality, given the close interactions existing among remittances, exchange rates and output, decisions in connection with the latter might have crucial consequences on the dynamics of the economic system.

Several limitations have been realized in this study that future research might look into. This work was not able to look into all Asian countries, due to data limitation.

Therefore, we suggest that scholars reinvestigate this nexus centering on various economies, use other macroeconomic indicators, employ an advanced methodology, and compare the findings with those gained in this article.

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