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## Article

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# Exploring the dynamic link between FDI, remittances, and ecological footprint in Pakistan: Evidence from partial and multiple wavelet based-analysis

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## ABSTRACT

The current study aims at studying the asymmetric nexus between foreign direct investment (FDI), foreign remittances inflow (RMIT), and ecological footprint (EF) for Pakistan from 1976Q1-2020Q4. To this end, our article deploys Morlet's wavelet method. Simply, the recent paper employs Wavelet Coherence Transform (WCT), Partial and Multiple Wavelet Coherence (PWC & MWC) to divulge the dynamic nexus among the series under study. With respect to frequency and time domains, the significant wavelet coherence and robust lead-lag association are inferred. Furthermore, FDI exhibits a strong co-movement with EF, implying that variations in the FDI inflows are highly sensitive to the environment. Likewise, RMIT demonstrates a significant association with EF. Besides, the frequency domain causality test validates our findings by confirming the causal links of FDI and RMIT with EF. Based on the results, some salient policies are suggested to tackle the exigency of environmental pollution.

## Introduction

From the last two decades, it is observed that the global economic growth has the sensitive link with the global environment. Approximately, majority of the environmentalists have the consensus on that GDP growth tends to degrade the environmental quality (Dogan et al., 2022; Chishti et al., 2021a). Therefore, the researchers have discerned several factors that affect the economic growth as well as the environmental quality. Among these determinants, foreign direct investment (FDI) and remittances are the most important factors of economic growth as well as environmental degradation (Salam & Chishti, 2022; Ahmad et al., 2019; Demena & Afesorgbor, 2020).

FDI, as the several scientific documents have confirmed, triggers the pace of GDP through enhancing the local employment, transferring the technologies, extending the markets, and attracting the advanced knowledge to the host economies (Noureen et al., 2022; Harding & Javorcik, 2011). However, one of the hottest issues among the environmentalist is the detrimental effects of FDI on environmental quality (Chishti et al., 2021b). More broadly, the GDP growth based on FDI may be negated on account of adverse effects of FDI on the atmospheric quality (Cole et al., 2011). Due to the likely negative environmental

related impacts of FDI, several economies prefer a selective type of foreign direct investment. Therefore, many economies encourage to host only so-called "Green FDI" that promotes green atmosphere along with fostering the economic development (Golub et al., 2011).

Considering the sensitivity of FDI with the environment and its environmental cost, developed economies have commenced to practice the strict environmental regulation; consequently, large polluting industries have started to move towards the developing economies. This situation is called "pollution haven hypothesis" (PHH). On the basis of PHH, it is also claimed that the shift of polluting industries to the developing economies tended to decrease the pollution in many developed economies (Kearsley & Riddell, 2010). As a result, it led to increase the ratio of FDI in developing world from 36 % to 47 % (Demena & Afesorgbor, 2020).

In a similar vein, foreign remittances inflow (RMIT) is deemed as a central source of international finance and a part of income on account of its worldwide economic influence (Meyer & Shera, 2017). Also, many studies have argued that remittances inflow plays a primary role in boosting the economic welfare and development. Furthermore, remittances inflow tends to provide the capital to impecunious households for commencing a small business; consequently, it leads to alleviate the

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harmful repercussions of poverty (Ahmad et al., 2019).

On the one side, RMIT boosts the demand through fostering the households' income level. On the other hand, RMIT provides the finance to the business community that has to face several difficulties to get financial support from commercial banks (Mottelle, 2011). In this way, RMIT support the small businesses by increasing the investment level that, ultimately, enhances the level of capital formation. Hence, the role of RMIT in improving the business activities also leads to damage the environmental quality. For example, Ayeche et al. (2016) and Caza-chevici et al. (2020) claim that RMIT causes to enhance the production capability by increasing the investment level; it tends to deteriorate the environment along with triggering the GDP growth.

Whereas the inflow of remittances in Pakistan is concerned, Pakistan got the place in top ten global economies which have received the most remittances in 2020 and the share of RMIT was 9.9 % of the Pakistan's GDP (State Bank of Pakistan, 2021). Since 2018, the Pakistan's economy has been enjoying the consistent rise in foreign remittances inflow and in 2021, its growth was recorded by 26 % (US\$ 21.5 billion). Further, Fig. 1 depicts the % change in RMIT from 2017 to 2021. Besides, Fig. 2 shows the country-wise inflow of RMIT in Pakistan in FY 2020 and 2021. In 2021, Pakistan has received the major chunk of RMIT from Saudi Arabia, followed by UAE, USA and UK.

Similarly, Pakistan also enjoys a huge amount of FDI from different economies. For instance, China is at the top in investing in Pakistan into CPEC-related projects and its total investment is recorded by 46.7 % of Pakistan's total FDI inflow in 2021. Likewise, Hong Kong and UK also do investment in Pakistan that was 7 % of the total FDI from each economy. Further, the details are presented in Fig. 3. Additionally, Fig. 4 indicates the sector-wise FDI (in % of total FDI) in Pakistan. For example, the largest part of FDI is invested to power sector that is recorded by 55 % of total FDI. It is followed by financial business and oil & gas explorations sectors in which 15 % and 12 % of the total FDI were invested in 2021.

The Pakistan's economy has been enjoying a significant rise in the inflows of RMIT and FDI, that substantially contributes to trigger the economic activities. Since the activities are associated with the environmental quality. Hence, it is imperative to explore the effects of RMIT and FDI on the environment. Therefore, the current study postulates the following research question.

**Research Question:** *How the FDI and remittances affect the ecological footprint in Pakistan?*

In this context, we claim that the less attention is paid to nexus between FDI, RMIT and the environmental quality, specifically, in the case of Pakistan. Therefore, the current study aims at exploring the dynamic nexus between FDI, RMIT and the environmental quality in Pakistan. In this context, our paper extends the existing literature in the following ways. Firstly, this is the first study, to the best of our knowledge, that investigates the nexus between FDI, RMIT and the environmental

quality in Pakistan. Secondly, our study, unlike the prior literature in the context of Pakistan, deploys ecological (EF) footprint as a proxy for environmental quality since the ecological footprint is more comprehensive and broader proxy than carbon dioxide emissions (CO<sub>2</sub>e) to measure the environmental condition (Alola et al., 2019; Sharif et al., 2021). Thirdly, our study utilizes the quarterly data for FDI, RMIT and ecological footprint to divulge more informative and policy-oriented findings. Fourthly, our study uses the family of wavelet analysis to find the more informative and asymmetric results unlike the previous studies that rely on estimating the on average and linear coefficients. Lastly, the frequency domain causality test propounded by Breitung and Candelon (2006) is applied in order to affirm the robustness of the findings.

The remainder of the paper possesses the following order. The Section 2 explains the literature-based link between FDI, RMIT and ecological footprint. In Section 3, the econometric model is discussed along with highlighting the reason for choosing the econometric methodology. The Section 4 elaborates the data sources. In Section 5, the discussion on the results is presented. In the last section, the findings are summarized along with presenting some important policies.

## Literature review

In this section, we document the review of previous studies on the nexus between FDI-EF and RMIT-EF. To this end, this section is classified into the following parts: (i) environmental pollution and ecological footprint, (ii) FDI and environment nexus, and (iii) RMIT-environment nexus.

### Environmental pollution and ecological footprint

Environmental pollution has become the most pressing challenge for the global economies. The pacy economic growth puts the pressure on the utilization on the resources including energy resources. Most of the economies rely on the deployment of fossil fuels to meet the energy demand; this process tends to increase the exigency of environmental pollution (Chishti & Sinha, 2022). To measure the environmental pollution, researchers deploy various proxies. For instance, several scholars (Jahanger et al., 2022a, Jahanger et al., 2022b; Chishti & Dogan, 2022; Weimin & Zubair Chishti, 2021; Chishti et al., 2020a; Chishti et al., 2021; Rehman et al., 2021a; Teng et al., 2020; Weimin et al., 2021; Ullah, Chishti & Majeed, 2020; Rehman et al., 2021b; Chishti et al., 2021b; Ullah, Majeed, & Chishti, 2020) have used carbon dioxide emissions (CO<sub>2</sub>e) as proxy to measure the environmental pollution. Likewise, some scholars (Usman et al., 2020) have utilized Methane (CH<sub>4</sub>), Nitrous oxide (N<sub>2</sub>O), and Fluorinated gases as proxy for environmental degradation.

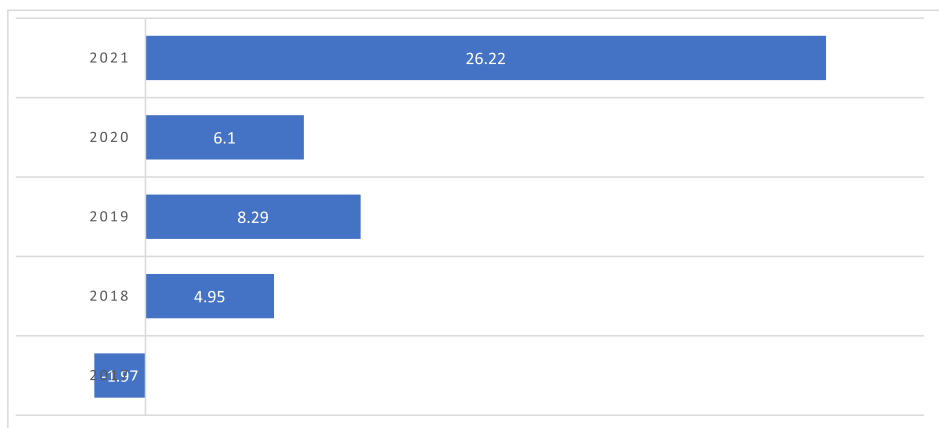


Fig. 1. Annual % change in remittances inflow in Pakistan. Source: State Bank of Pakistan (2021).

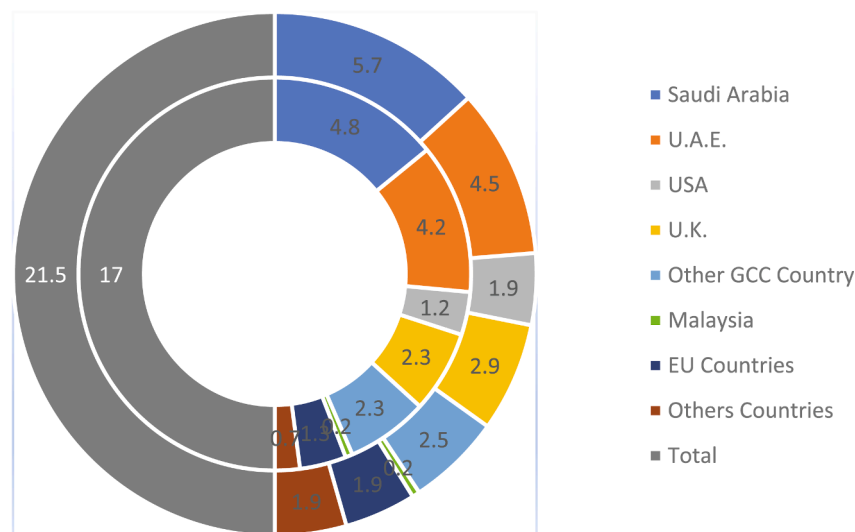


Fig. 2. Country-wise RMIT in FY 2020 & 2021 in Pakistan. Source: State Bank of Pakistan (2021).

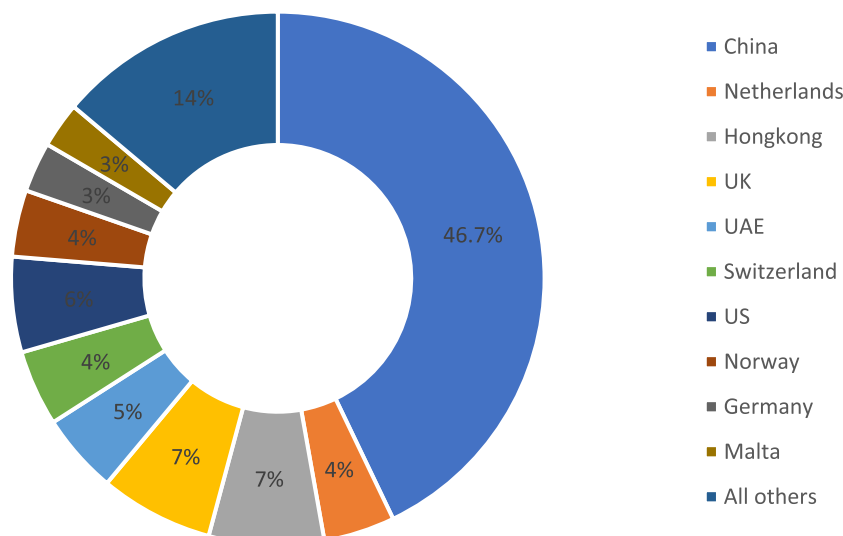


Fig. 3. Country-wise FDI inflows (in % of total FDI) in Pakistan. Source: State Bank of Pakistan (2021).

However, the recent studies suggest that ecological footprint (EF) can be a better measure to reflect the true picture of the environmental degradation. In this context, Vačkář (2012) argues that EF is a holistic indicator to measure the anthropogenic pressure on the environmental quality. In addition, Ansari (2022), Caglar et al. (2022), Liu et al. (2022), Ahmed et al. (2022), Huang et al. (2022), Aloa et al. (2019) and Sharif et al. (2021) assert that EF is broader and comprehensive proxy as compared to other proxies such as CO<sub>2</sub>e, CH<sub>4</sub>, N<sub>2</sub>O etc. since it covers the cropland, fishery, forestry, grazing land and CO<sub>2</sub>e. Therefore, to use the EF as a proxy for environmental pollution can present the better and more reliable results. Hence, the current study prefers to utilize EF to measure the environmental quality.

#### Foreign direct investment-environment nexus

Keeping in view the ample body of literature on nexus between FDI and environmental quality, overall, the effects of FDI on the environment can be classified into three categories: positive, negative and neutral effects. Whereas the positive effects of FDI are concerned, these are based on the pollution halo hypothesis. It means that the firms from developed world deploy green technologies while investing in

developing economies; it tends to improve the green environment. Hence, there are several studies that validate the presence of pollution halo hypothesis. For example, Duodu et al. (2022) for African nations, Musah et al. (2022) for G-20 economies, Fahad et al. (2022) for China, Chen et al. (2022) for China, Arif et al. (2022) for selected economies, Abbass et al. (2022) for South Asia, Nhung and Quang (2022) for Asian nations, Cil (2022) for Turkey, Zhao et al. (2022) for China, Demena and Afesorgbor (2020), Rafique et al. (2020) for BRICS, Xing et al. (2017) for China, Zhang and Zhou (2016), Pazienza (2015) for OECD economies, Al-mulali (2012) for GCC economies, Pao and Tsai (2011) for BRICS confirm that inflow of FDI results in enhancing the quality of the environment.

On the other hand, there is a strand of studies that concludes that FDI causes to degrade the environment. This is based on the pollution haven hypothesis, i.e., the producers of the countries having the tight environmental regulations start the production process in the economies that possesses the laxer environmental norms (Chishti et al., 2021). In this context, Shahbaz et al. (2018) for France, Shahbaz et al. (2015) for several selected economies, Abdouli and Hammami (2017) for MENA countries, Paramati et al. (2016) for 20 emerging economies, Tang (2015) for Vietnam, Solarin et al. (2017) for Ghana, Hitam and Borhan

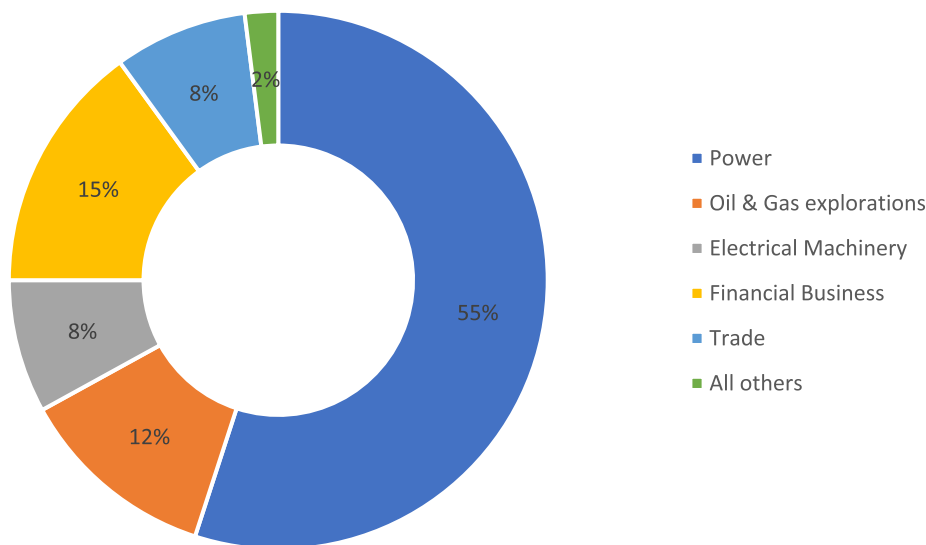


Fig. 4. Sector-wise FDI in Pakistan (in %). Source: State Bank of Bank (2021).

(2012) and Lau et al. (2014) for Malaysian, He (2006) and Ren et al. (2014) in China assert that the rise in the FDI tends to escalate the ratio of environmental degradation. On the base of above discussion, it can be inferred that the nexus between FDI and the environment are still under question and it requires further empirical exploration. Besides, majority of the studies discussed above rely on the CO<sub>2</sub>e as a proxy for environmental pollution. Therefore, it is rational to explore the effects of FDI on the environment while using ecological footprint that is broader and more comprehensive indicator.

**Hypothesis I:** *There exists a positive link between FDI and ecological footprint.*

#### Remittances and environment nexus

Since the inflow of foreign remittance trigger the production process through increasing the consumer demand for good; it tends to affect the environment due to use of a huge amount of energy. Hence, it is important to explore the effects of remittances (RMIT) on the environment. In this context, there are many scholars that seek the dynamic nexus between RMIT and the environment. For instance, Yang et al. (2020) checks the effects of remittances on the environment of the selected 97 economies. Likewise, Brown et al. (2020) explores the effects of RMIT for Jamaica. Also, Islam (2022), Ahmad et al. (2022), Yakubu et al. (2022), Zafar et al. (2022), Liu et al. (2022), Jafri et al. (2022), Mujtaba & Ashfaq (2022), Li and Fu (2022), Ali et al. (2022), Khan et al. (2019), Yang et al. (2021), Ahmad et al. (2019), Sharma et al. (2019), Neog and Yadava (2020) examine the influence of RMIT on the environment of top eight remittances receiving nations, Pakistan, selected economies, top ten remittances receiving nations, selected Asian nations, China, Pakistan, China, Pakistan, BRICS, BICS, China, Nepal, selected Asian economies, and India, correspondingly. The results determine that the rise in RMIT inflow tends intensify the environmental pollution in the respective economies. However, Doryn (2020) conclude that the environment shows no significant response to the RMIT.

Although there are several studies that explore the effects of RMIT on the environmental quality, however, all the studies suffer from the following issues. Firstly, all the documented studies use the CO<sub>2</sub>e as proxy for the environmental pollution while exploring the effects of RMIT on the environment. However, Aloa et al. (2019) and Sharif et al. (2021) claim that ecological footprint (EF) is the broader and comprehensive proxy as compared to CO<sub>2</sub>e. Hence, the deployment of EF as proxy can bring more better and significant results. Therefore, unlike the previous studies, the current relies on EF to measure the environmental

pollution. Secondly, the economy of Pakistan is listed in the top remittances receiving economies in 2020. However, less attention is paid to this, while the sensitivity requires more research to explore the dynamic effects of RMIT on the environment. Hence, the current study extends the prior literature body by exploring how RMIT affect the environment of Pakistan.

**Hypothesis II:** *There exists a positive link between remittances and ecological footprint?*

On the basis of the review of the pertinent literature body, we claim the following research gaps which yet require more research in this area. Firstly, although several studies testify the effects of FDI on the environment, however, the literature reports the inconclusive results that necessitates to do more exploration in this side. Secondly, the nexus between RMIT and environment is also explored, while taking the data of many economies. However, less attention is paid to the Pakistan economy which is listed in the top remittances receiving economies. Thirdly, majority the previous studies use CO<sub>2</sub>e as proxy for the environmental degradation. However, recently, Aloa et al. (2019) and Sharif et al. (2021) claimed that EF is more suitable proxy for the environmental pollution. In this context, the recent document extends the existing literature by exploring the effects of RMIT and FDI on the environment for Pakistan, while deploying the EF as a proxy for the environmental quality.

#### Model, methods and data

##### Theoretical underpinning

Since FDI and RMIT directly affects the GDP growth rate and GDP has the direct link with the environment (ecological footprint); hence it is rational to understand how FDI and RMIT can affect the EF. Therefore, in this section, we discuss the theoretical link between FDI, RMIT and the EF (proxy for environmental pollution). Whereas the theoretical link between RMIT and EF is concerned as Fig. 5 explains, it can be explained as follows. The remittances inflow tends to increase the level of personal income. The households divide their income into two parts: consumption and saving. Due to RMIT, consumption as well as saving level rise. The increase in consumption put the pressure on aggregate demand; it leads to enhance the industrial production which requires a massive amount of energy. Since majority of the economies like Pakistan rely on the fossil fuels, hence, the rise in economies activities results in increasing the EF along with improving GDP ratio. On the other hand, the rise in saving due to RMIT cause to escalate the bank deposits; this

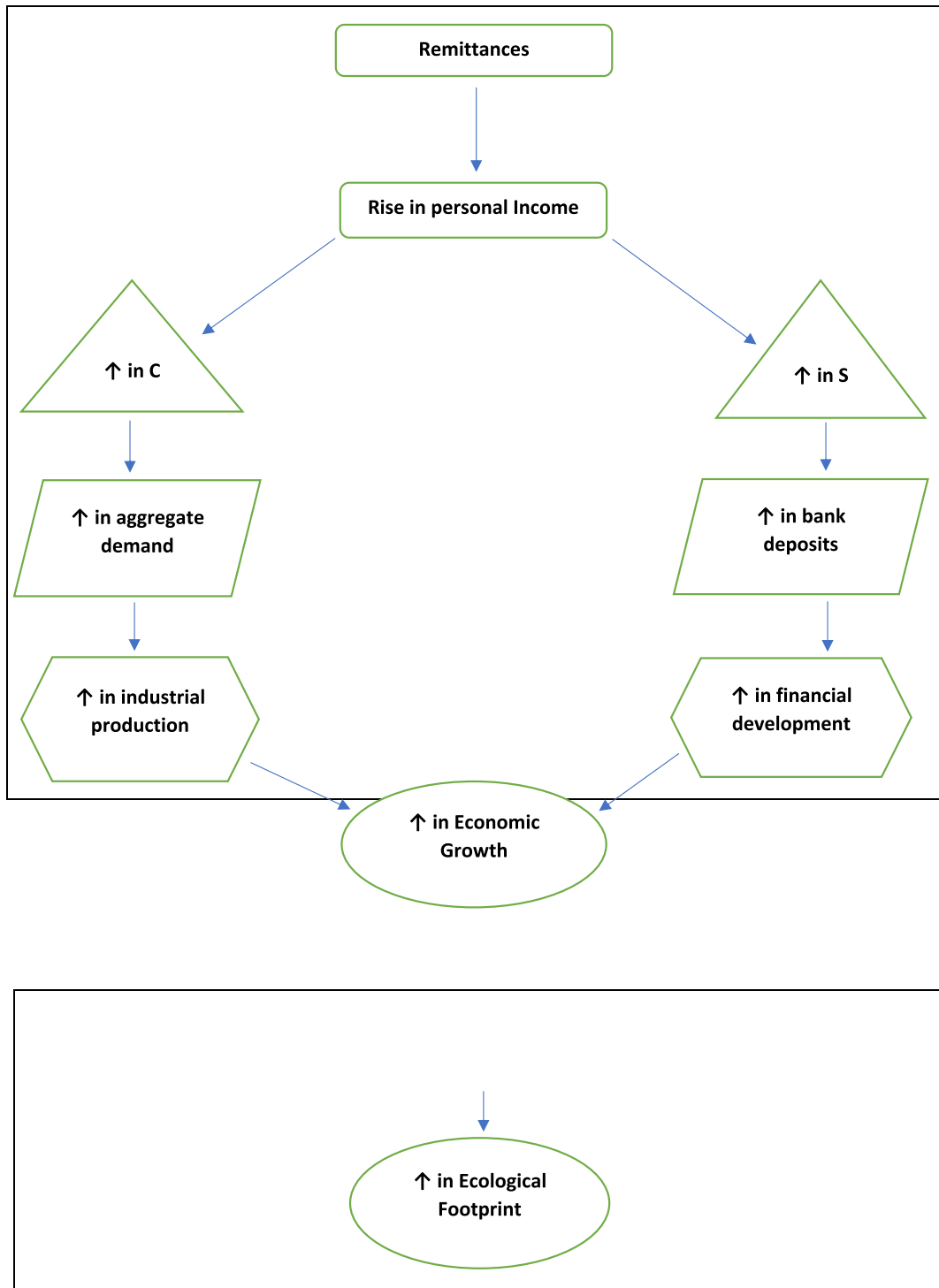


Fig. 5. Theoretical nexus between remittances and ecological footprint.

process enhances the financial development and it triggers the GDP growth. Ultimately, it also affects the environmental quality by increasing the EF (Ahmad et al., 2019). In this way, RMIT contributes towards to affect the environmental quality.

Similarly, FDI also influence the ratio of EF as Fig. 6 depicts. The reason being, the inflow of FDI results in increasing the quantity of industrial plants. The erection and extension of the new plants tends to speed up the production process which puts the pressure on energy sector to meet the energy demand. To this end, the producers rely on the cheap and dirty technologies to provide the instant energy;

consequently, such economic activities tend to increase the ratio of EF. On the basis of theoretical underpinning, we specify the following model:

$$EF_{it} = a_0 + a_1 FDI_t + a_2 RMIT_{it} + \varepsilon_t \quad (1)$$

#### Econometric model and methodology

Based on the theoretical underpinning in previous section, we can specify the following econometric model:

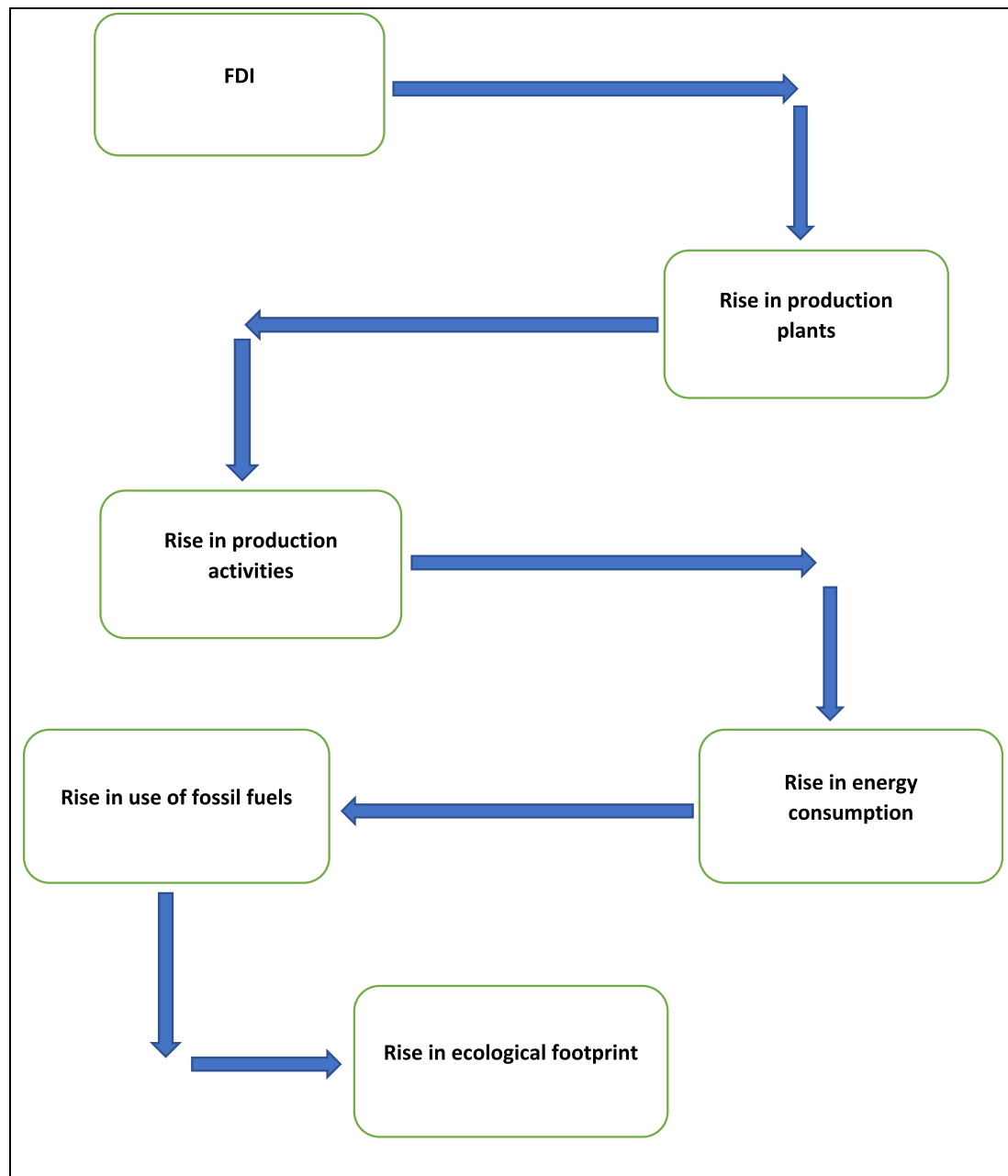


Fig. 6. Theoretical nexus between FDI and ecological footprint.

$$EF_t = \beta_0 + \beta_1 FDI_t + \beta_2 RMIT_t + \varepsilon_t$$

(2)

Where  $FDI_t$  = foreign direct investment,  $RMIT_t$  = remittances inflow, and  $EF_t$  = ecological footprint. To compute the above model, our study purposes the wavelet transform approach.

#### Wavelet approach

The current article prefers to deploy the wavelet transform approach due to following reasons. Firstly, this approach allows the decay of localized frequencies even if the object is non-uniform and stationary unlike the Fourier analysis (Percival & Walden, 2000). Secondly, this technique can analyze the non-normally distributed and stationary to non-stationary data efficiently unlike the other time series methods. Thirdly, it can handle the nonlinearity by categorizing the series into positive and negative divergents. Fourthly, This approach classifies the modelled series into short, medium, and long modules while analyzing

the nexus among the series. Fifthly, it can explore the lead-lag nexus among two selected series. Lastly, wavelet coherence transform has the ability to divulge the causal association between two modelled series. However, this technique, just like other asymmetric time-series methods, can present the comprehensive and directional results if the model has the two to three variables for analysis (Goodell & Goutte, 2020; Habib et al., 2021).

Based on the several salient features discussed above, we opt to deploy the wavelet approach. The following tools of the wavelet transform approach are utilized to obtain the findings: (i) the continuous wavelet transform (CWT), (ii) the wavelet transform coherence, (iii) the partial wavelet coherence, and (iv) the multiple wavelet coherence. The discussion on the each tool is given as follows.

#### The continuous wavelet transform (CWT)

To obtain the continuous wavelet transformation, the following is



deployed:

$$W_x(m, n) = \int_{-\infty}^{\infty} x(t) \frac{1}{\sqrt{n}} \psi\left(\frac{t-m}{n}\right) dt \quad (3)$$

Where  $m$  (i.e. a scale parameter) denotes the specific extension of the wavelet, while  $n$  indicates the location that is used to capture the time information. In addition, one of the salient features of the CWT is to decompose and reconfigure a time series  $x(t) \in L^2(R)$  properly as shown below:

$$x(t) = \frac{1}{C_\Psi} \int_0^\infty \left[ \int_{-\infty}^\infty W_x(m, n) \Psi_{m,n}(t) du \right] \frac{dn}{n^2}, n > 0 \quad (4)$$

Another remarkable feature of CWT is retaining the momentum of time series analysis, that can be expressed as follows:

$$\|x\|^2 = \frac{1}{C_\Psi} \int_0^\infty \left[ \int_{-\infty}^\infty |W_x(m, n)|^2 dm \right] \frac{dn}{n^2} \quad (5)$$

The feature presented in Eq. (4) is utilized in the recent article to explain the wavelet coherence, i.e., it has the ability to quantify the natural inference between the structure of the modeled series.

#### The wavelet transform coherence (WTC)

Next, the current article need to deploy wavelet coherence to capture the association between RMIT, FDI, and EF. The noteworthy characteristic of the wavelet coherence is that: it highlights the regions in a particular time–frequency domain where unpredicted and considerable oscillation occur in the co-moment pattern of the selected time series. Thereby, Torrence and Webster (1999) present the framework to express the wavelet transform coherence in the mathematical form that can be written as:

$$R^2(m, n) = \frac{|N(N^{-1} W_{xy}(m, n)|^2}{N(N^{-1} |W_x(m, n)|^2) N(N^{-1} |W_y(m, n)|^2)} \quad (6)$$

Where  $0 \leq R^2(m, n) \leq 1$ . Furthermore, if the value of  $R^2$  approaches to zero, it indicates the no correlation. However, if the value is equal to one, it shows the high level of correlation.

#### The partial wavelet coherence (PWC)

The current research document, next, uses the partial wavelet coherence (PWC) in order to explore the basic correlation among the targeted series. This novel method can divulge the wavelet coherence between any two series such as  $x_1$  and  $x_2$ , while eliminating the influence of third series (i.e.,  $y$ ). Hence, the coherence between  $x_1$  and  $x_2$ ,  $x_1$  and  $y$ , and  $x_2$  and  $y$  can be elaborated as:

$$R(x_1, x_2) = \frac{S[W(x_1, x_2)]}{\sqrt{S[W(x_1)]S[W(x_2)]}}; \quad (7)$$

$$R^2(x_1, x_2) = R(x_1, x_2).R(x_1, x_2)^*; \quad (8)$$

$$R(x_1, y) = \frac{S[W(x_1, y)]}{\sqrt{S[W(x_1)]S[W(y)]}}; \quad (9)$$

$$R^2(x_1, y) = R(x_1, y).R(x_1, y)^*; \quad (10)$$

$$R(x_2, y) = \frac{S[W(x_2, y)]}{\sqrt{S[W(x_2)]S[W(y)]}}; \quad (11)$$

$$R^2(x_2, y) = R(x_2, y).R(x_2, y)^*; \quad (12)$$

#### The multiple wavelet coherence (MWC)

Like multiple correlation, this method is deployed to analyze the coherence between multiple selected series. Since it integrates the effects of third variable while examining the coherence between two variables, this method provides the more information as compared to the PWC. The mathematical form of MWC can be transcribed as:

$$RM^2(y, x_2, x_1) = \frac{R^2(y, x_1) + R^2(y, x_2) - 2Re[R(y, x_1).R(y, x_2)^*.R(x_2, x_1)^*]}{1 - R^2(x_2, x_1)} \quad (12)$$

In Eq. (12),  $RM^2$  demonstrates the wavelet power's proportion and it also elucidates how much independent series (i.e.,  $x_2, x_1$ ) explain the dependent variables, viz,  $y$ . To inspect the MWC's significance level, the current study utilizes the Monte Carlo method.

#### Data

The current study tends to analyze the nexux between FDI, RMIT and EF in Pakistan for 1976Q1 and 2020Q4. To this end, the data for FDI and RMIT is taken from World Development Indicators (WDI) (See: <https://databank.worldbank.org/source/world-development-indicators#>). Besides, the data for ecological footprint as a proxy to measure environmental pollution is retrieved from Global Footprint Network (See: <https://www.footprintnetwork.org/>). Additionally, the data is converted from annual to quarterly frequency by using quadratic match-sum method. Also, the data is in logarithmic form.

## Results and discussion

#### Stationarity and cointegration

The primary purpose of the article is to divulge the time–frequency causality between FDI, RMIT and ecological footprint. Prior to elaborating the main results, we discuss descriptive analysis to grasp the univariate characteristics of the modeled series. Besides that, the unit root (ADF and KSS) tests are deployed in order to ascertain the stationarity of the selected series (Chishti et al., 2020b). After that, the long-run association across the series is confirmed by cointegration test propounded by Johansen and Juselius (1990).

From descriptive analysis as Table 1 depicts, it can be inferred that there is significance difference between minimum and maximum values of the EF, FDI and RMIT, indicating the non-linearity in the modeled series. Additionally, the outcome of the Jarque-Bera test affirms the non-normal nature of the series in the current study. Since the descriptive statistics indicate the non-linearity of the series, our study deploys ADF (linear) as well as KSS (non-linear) unit root tests. The findings, as Table 2 documents, assert that the first difference turns all the modeled variables into stationary series. Therefore, we can say that all the

**Table 1**  
Descriptive statistics.

	EF	FDI	RMIT
Mean	0.778021	1.09E+09	6.31E+09
Median	0.803290	5.32E+08	2.54E+09
Maximum	0.926129	5.59E+09	2.61E+10
Minimum	0.633942	8220530.	4.12E+08
Std. Dev.	0.081966	1.35E+09	7.20E+09
Skewness	−0.321953	1.862215	1.364490
Kurtosis	2.004508	6.291309	3.451671
Jarque-Bera	2.635538	46.32019	14.34625
Probability	0.267732	0.000000	0.000767



**Table 2**  
Unit root tests.

		At Level		
		EF	FDI	RMIT
ADF test	<i>t</i> -Statistic	−0.3296	−0.6082	−1.9652
	<b>Prob.</b>	<b>0.9124</b>	<b>0.0092</b>	<b>0.3007</b>
	n0		***	n0
KSS (Non-linear) test	<i>t</i> -Statistic	−2.6262	−0.6126	−1.7758
	<b>Prob.</b>	<b>0.2711</b>	<b>0.0394</b>	<b>0.7005</b>
	n0		**	n0
		At First Difference		
		d(CO2)	d(EC)	d(FFC)
ADF test	<i>t</i> -Statistic	−3.7744	−7.0607	−5.1356
	<b>Prob.</b>	<b>0.0059</b>	<b>0.0000</b>	<b>0.0001</b>
		***	***	***
KSS (non-linear) test	<i>t</i> -Statistic	−3.7294	−6.9963	−5.5024
	<b>Prob.</b>	<b>0.0300</b>	<b>0.0000</b>	<b>0.0002</b>
		**	***	***

\*\*\* = Significant at 1 %, \*\* = Significant at 5 %.

variables in the study are I(1).

Next, we apply the [Johansen and Juselius \(1990\)](#) cointegration test in order to affirm the long-run association across the series. The outcome of the test, as reported by [Table 3](#), shows that the cointegration exists in both cases of trace and maximum eigenvalue. It implies that the long-run association between FDI, RMIT and EF is confirmed. Therefore, we can confidently proceed towards the interpretations of the main results.

#### Wavelet decomposition

By far, the literature review demonstrates that a few studies are available that focus on divulging the nexus between the variables selected in the current paper while deploying the wavelet framework. The notable thing is: there are several periods in the different variables used in a study which require the appropriate time scales for explanation during the specific analysis ([Mishra et al., 2019](#)). It necessitates that analysis should be done at various time horizons, while applying the time–frequency techniques, that are generally called “Wavelet”. In this context, a orthogonal mechanisms (i.e. d1 to d6) based graph of each series is erected to highlight the various frequency mechanisms of the raw data along with a smoothed series (S6). Observing these graphs as [Fig. 7](#) shows, it can be inferred that the short-run series exhibit the high frequencies while these series show a stable trend in the long run.

Next, the wavelet correlation method is used to analyze the association between the series under study as [Fig. 8](#) reports. The outcome indicates that: EF and EFI shows the positive association in short, and medium run. In the long-run, this association becomes stronger. On the contrary, we find a negative association between EF and RMIT from short to long-run. Lastly, it is observed that FDI and RMIT do not show any significant association in the short and medium run. However, this link turns to positive association in the long-run.

#### Wavelet coherence transform (WCT)

The Wavelet coherence transform (WCT) elaborates the areas where

**Table 3**  
Cointegration test.

Trace (TR) test		Maximum eigenvalue (ME) test	
TR values	Critical value	ME values	Critical value
43.123***	38.824	27.147	23.771***
17.265	19.235	10.633	11.035
8.257	12.437	6.187	7.165

\*\*\* = Significant at 1 %.

two variables demonstrate the co-movement in frequency-domain and time, as [Fig. 9](#) illustrates. Simply, the WCT explores the cyclic and anti-cyclic nexus between the selected series. If the face of small arrows inside the border line is right-ward, it indicates that the modeled series are in-phase. The in-phase indicates the co-movement of the variable. If the face of the small arrows is right-upward, it indicates that the both series are moving in the same direction while the dependent variable is leading the independent series. On the other hand, if the face of the small arrows is right-downward, it indicates that the both series are moving in the same direction while the independent variable is leading. Further, if the face of small arrows in-side the border line is left-ward, it indicates that the modeled series are out of phase, implying that both series move in opposite direction. In out of phase, if the face of the small arrows is left-upward, it indicates that the both series are moving in the opposite direction while the independent variable is leading the independent series. On the other hand, if the face of the small arrows is left-downward, it indicates that the both series are moving in the inverse direction while the dependent variable is leading. In [Figs. 9–11](#), Besides, the 0–50 points on the time-axis represents the time from 1976Q1 to 1987Q4, the 50–100 points represents the time from 1988Q1 to 2000Q2, the 100–150 points show the time from 2000Q3 to 2012Q4, and the 150 to onward points show the time from 2013Q1 to 2020Q4.

From [Fig. 9\(a\)](#), we can observe the correlation trajectory between ecological footprint EF and FDI, while focusing on the small arrows cluster. For example, during the short run (a frequency region of 4–8), we see in-phase arrows that indicates the significant cyclical positive nexus between EF and FDI. Approximately, this is the time period of 2000(Q1–Q4) and 2012Q1–2015Q4, the right-upwards faced arrows can be observed, implying that EF is leading in the short-run. Also, the same scenario is witnessed for the right-downward faced arrows during the period of 1974Q1–1975Q4 and 2011Q1 and 2013Q4 during the short-run, indicating that FDI is leading. During the medium and long-run (a frequency region of 8–32), FDI and EF do not show any significant movement. In the very long-run (a frequency region after 32), FDI significantly leads to EF as the in-phase arrows are right-downward. It implies that FDI significantly increases the EF in the very long-run.

Next, [Fig. 9\(b\)](#) exhibits that there exists (i) anti-phase nexus between EF and remittances (RMIT) during 1979(Q1–Q4) and 1996(Q1–Q4) with the leading effect of RMIT, (ii) in-phase nexus during 1983–1990 with the leading effect of EF, and (iii) in-phase nexus during 2003(Q1–Q4) and 2008Q1–2010Q4 with the leading effects of RMIT in the short-run. In the long-run, an anti-phase situation is noticed in which EF is leading.

Lastly, in [Fig. 9\(c\)](#), we observe an anti-phase scenario between FDI and RMIT during 1980(Q1–Q4) and 2009Q1–2012Q4 in the short-run in which FDI is leading. Further, the period of 200(Q1–Q4) shows in-phase situation with the leading effects of RMIT and the period of 2007Q1–2008Q4 indicates an anti-phase correlation between the series under study while FDI is leading in the short-run. Also, in the medium run, we observe an anti-phase association, while the RMIT is leading.

#### Partial and multiple wavelet coherence

Next, we discuss the findings of partial and multiple wavelet coherence while focusing on the coherence plots as [Figs. 10 and 11](#) indicate, respectively. For instance, [Fig. 10\(a\)](#) reports the outcome of partial wavelet coherence (PWC) between ecological footprint (EF) and FDI while ignoring the influence of remittances (RMIT). Several small and a large red island during short run (0–4 and 4–8 time–frequency) in 1980(Q1–Q4), 1990(Q1–Q4), 1991(Q1–Q4), 1994(Q1–Q4), 1998(Q1–Q4), and 2013Q1–2016Q4 demonstrate a strong correlation, implying that FDI significantly increase the EF. Also, this significant association is observed during medium-run for 2001(Q1–Q4) and very long-run for 1992Q1–2005Q4. Economically, the inflow of FDI results in increasing the quantity of industrial plants. The erection and extension of the new plants tends to speed up the production process which puts the pressure

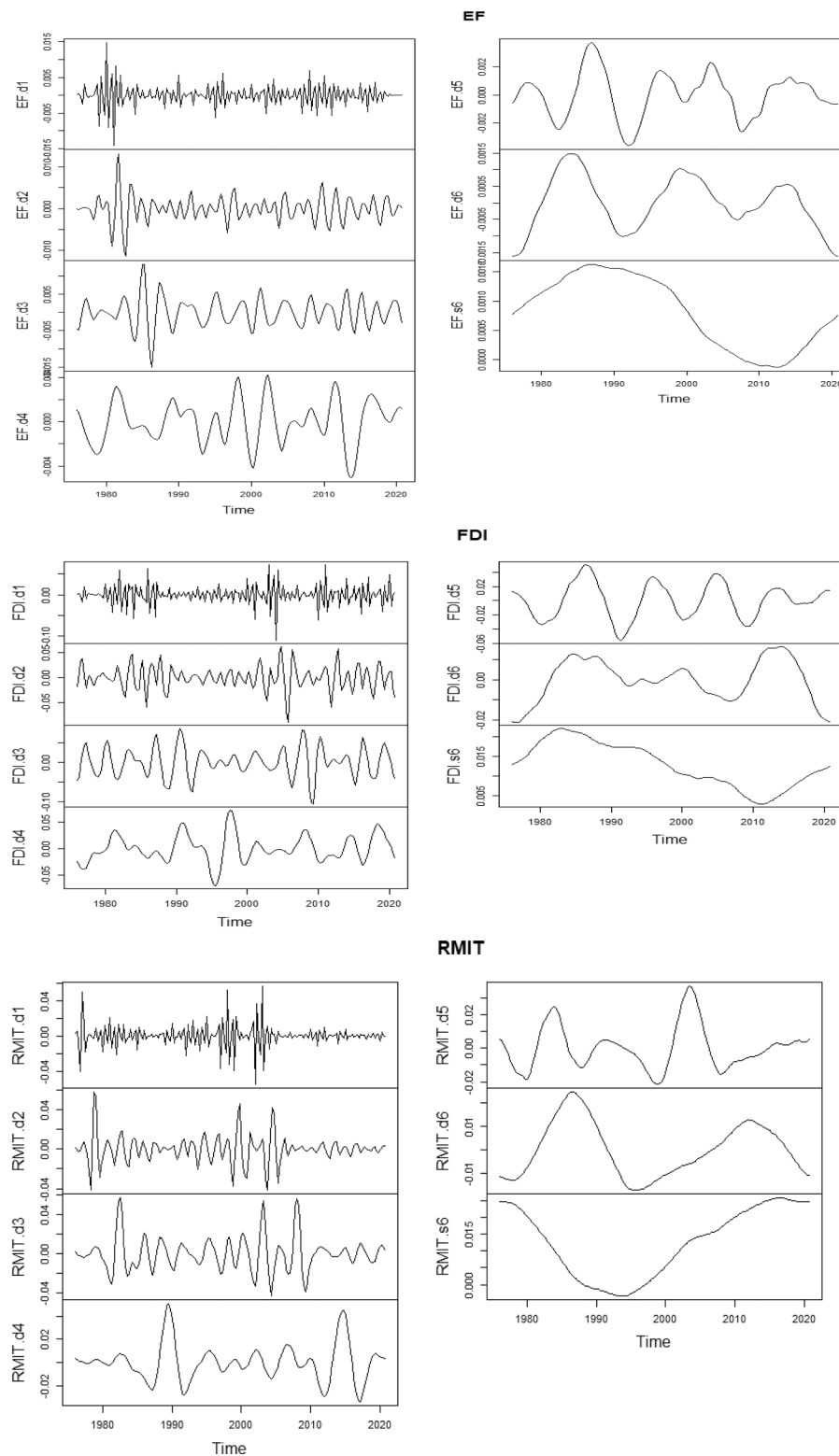


Fig. 7. Wavelet decomposition of selected series.

on energy sector to meet the energy demand. To this end, the producers rely on the cheap and dirty technologies to provide the instant energy; consequently, such economic activities tend to increase the ratio of EF. Our results are in the line with Adeel-Farooq et al. (2021), Bulus and Koc (2021), and Polloni-Silva et al. (2022).

Similarly, the significant association between EF and RMIT while excluding the effects of FDI is witnessed in the all-time periods (from

very short to very long-run), implying that RMIT significantly boosts the EF in Pakistan. Furthermore, several red-circles are present in Fig. 10(b) for the period of 1979(Q1-Q4)-1981(Q1-Q4), 1990Q1-1992Q4, 2008Q1-2009Q4, and 2018Q1-2019Q4 in region 0–4 & 4–8 (in the short-run). Also, a strong correlation is observed for region 8–16 (medium-run) in 1982(Q1-Q4) and 2001Q1-2002Q4. In the very-long, the outcome confirms the correlation for 1994Q1-2002Q4, again indicating

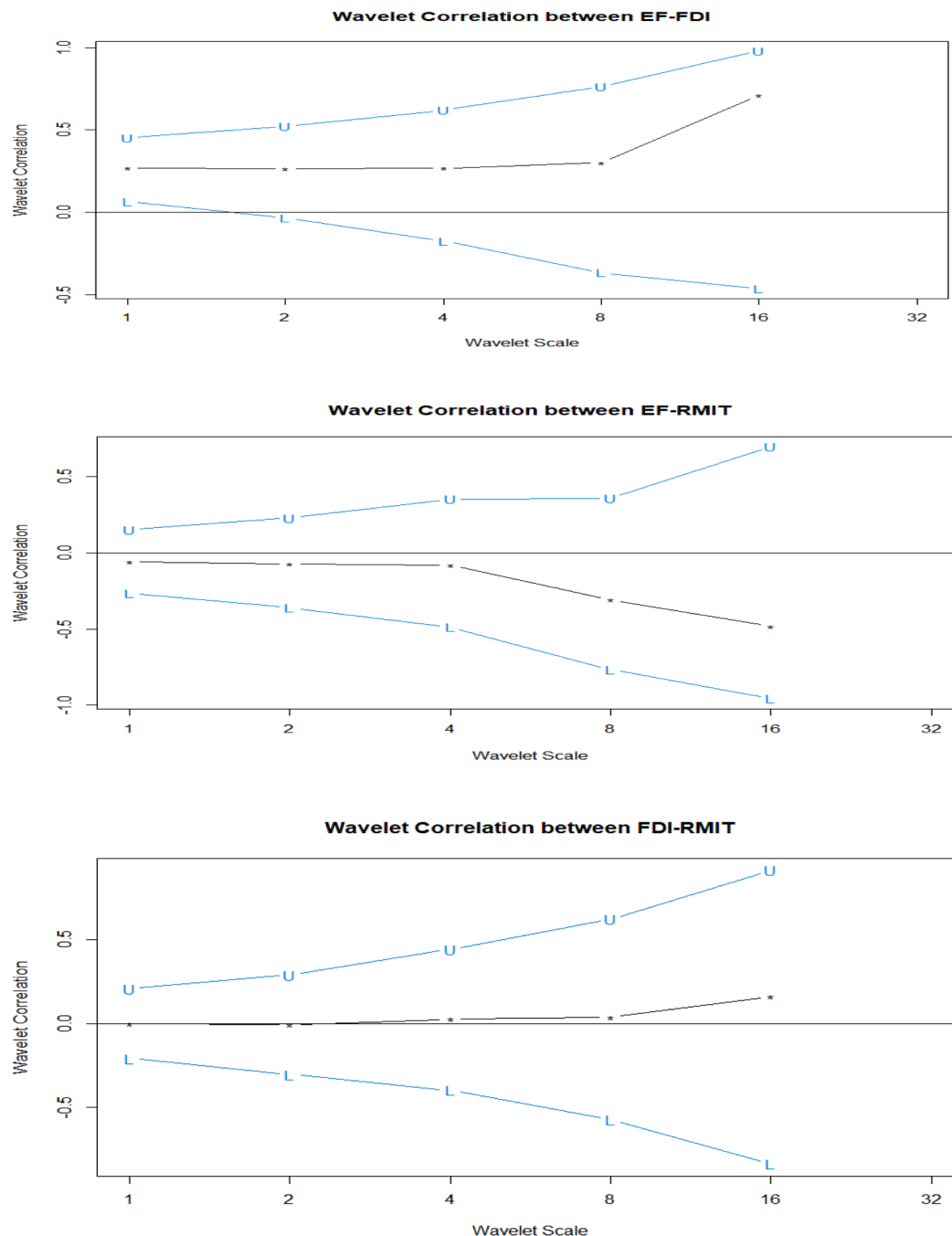


Fig. 8. Wavelet correlation results.

that RMIT creates the detrimental effects on environmental quality by increasing the EF. The reason being, the remittances inflow tends to increase the level of personal income. The households divide their income into two parts: consumption and saving. Due to RMIT, consumption as well as saving level rise. The increase in consumption put the pressure on aggregate demand; it leads to enhance the industrial production which requires a massive amount of energy. Since majority of the economies like Pakistan rely on the fossil fuels, hence, the rise in economies activities results in increasing the EF along with improving GDP ratio. On the other hand, the rise in saving due to RMIT cause to escalate the bank deposits; this process enhances the financial development and it triggers the GDP growth. Ultimately, it also affects the environmental quality by increasing the EF. The same findings are reported by [Nwani et al. \(2022\)](#), [Jamil et al. \(2021\)](#), and [Usman and](#)

[Jahanger \(2021\)](#).

Whereas the association between FDI-RMIT while ignoring the impact of EF is concerned, the PWC in [Fig. 11 \(c\)](#) shows the similar results as of [Fig. 10 \(b\)](#). It means that several red islands in different regions (i.e., 0–4, 4–8, 8–16, and 16–32) confirm a strong correlation between FDI and RMIT. Besides, the notable thing is that there is a considerable difference between the outcome of WCT and PWC as the results of the later method also affirm the very-run correlation among the series under study.

After elaborating the outcome of PWC, we put a question: do the results of multiple wavelet coherence (MWC) create the difference as compared to the PWC's results. The answer is "Yes". The MWC also considers the effects of third series while reporting the co-movement between two series. The discussion on the findings of MWC comes as

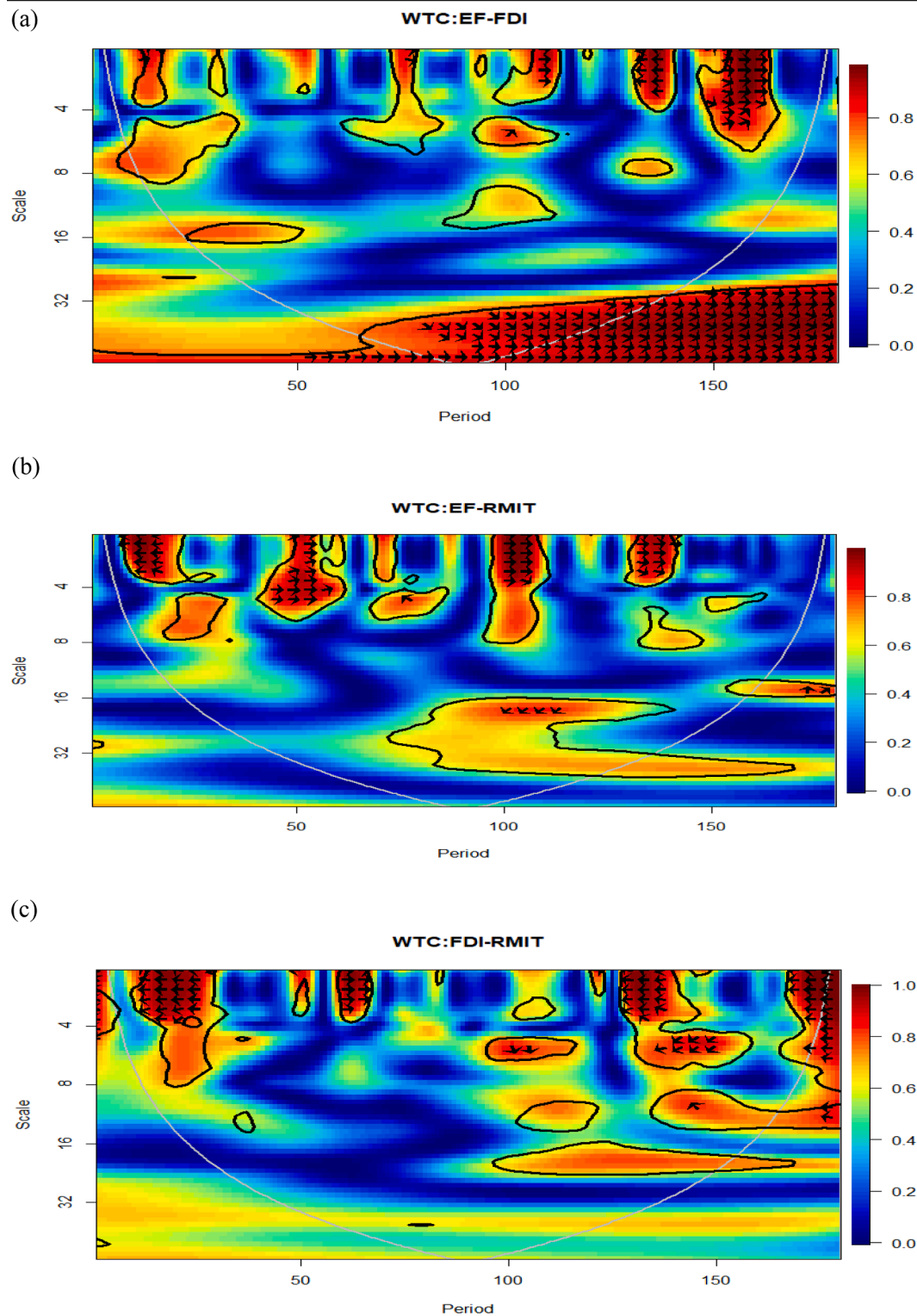


Fig. 9. Wavelet coherence transform of EF, FDI, and RMIT.

follows. As Fig. 11(a) shows, MWC treats the EF as dependent series, while FDI and RMIT are considered as explanatory series. The integration of FDI and RMIT as independent variables explains the oscillations in the EF. There are several red-colored small and large islands in all frequency bands (viz, 0–4, 4–8, 8–16, and 16–32) during all periods of time (i.e., very short, short, long and very long-run). Overall, the findings confirm that FDI significantly predict the intensity of environmental degradation while considering the influence of RMIT. On the base of the

MWC's outcome, we can infer that the inflows of FDI and RMIT in Pakistan considerably escalates the environmental pollution by increasing ecological footprints, approximately, in each time period.

The Fig. 11(b) divulges the effects of EF and RMIT on FDI. In this context, the results determine the many red-circles with black lines and deep color in all frequency domains such as 0–4, 4–8, 8–16, and 16–32 during the most of selected time period. The small and large deep red-colored islands affirm the significant influence of the linear

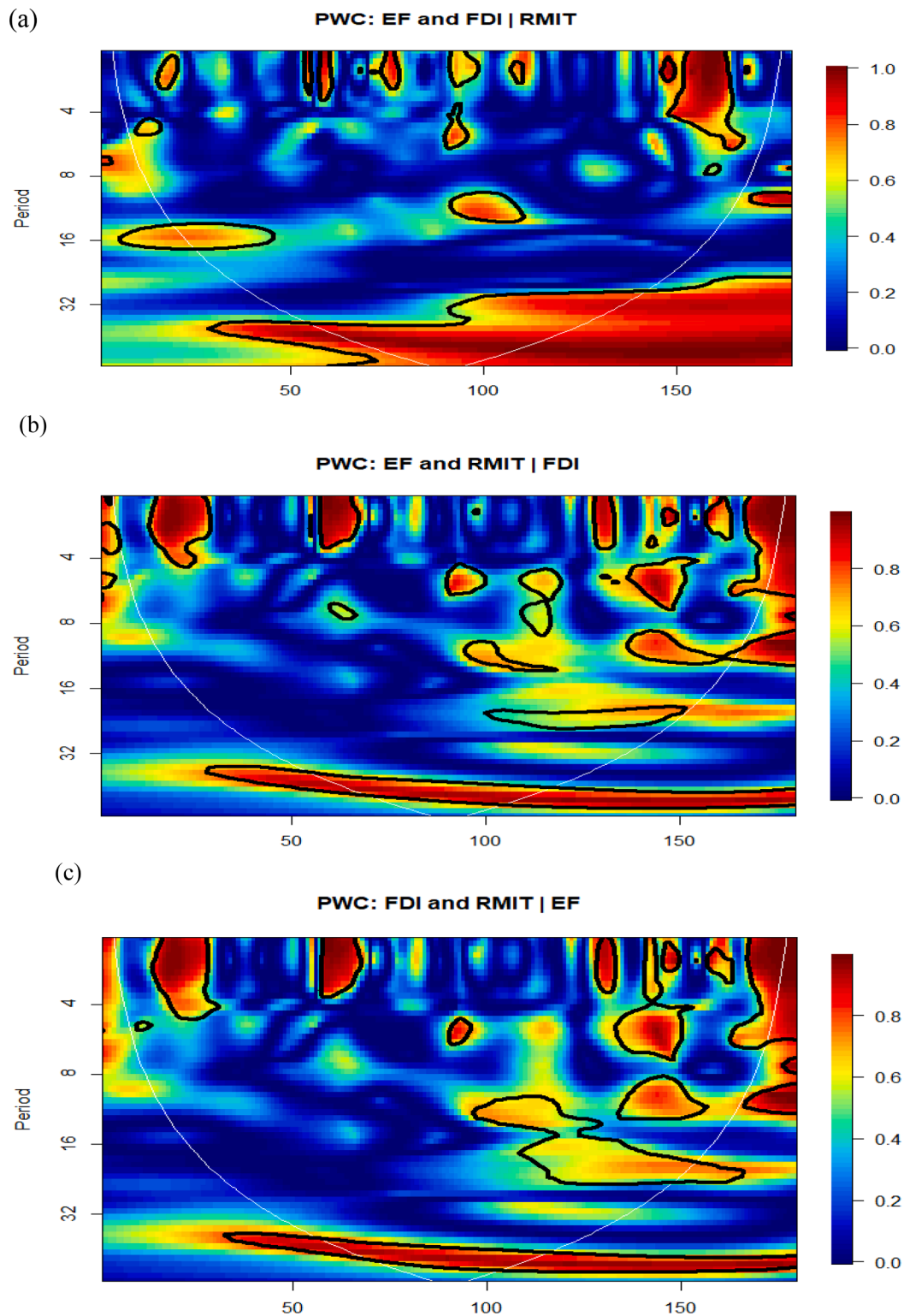


Fig. 10. Partial wavelet coherence.

integration of EF and RMIT on the series of FDI. Besides, this influence is stronger in the very long-run as compared to other time periods. Likewise, from Fig. 11(c), we can observe the several small and large circles with deep red-color in each frequency domain during all time periods. It implies that RMIT shows a significant association of the linear combination of EF and FDI. It can also be seen that the association is very-strong in the short-run, it becomes less strong in the medium-run, and again it becomes stronger in the long-run.

#### Robustness check

After discussing the findings, we also present the robustness check of the analysis. To this end, we use the frequency domain causality test propounded by [Breitung and Candelon \(2006\)](#). Essentially, the causality test reports that FDI and RMIT tend to possess a causal link with EF or not. Furthermore, the causality test confirms the causal association of independent series with dependent series if the blue line remains over

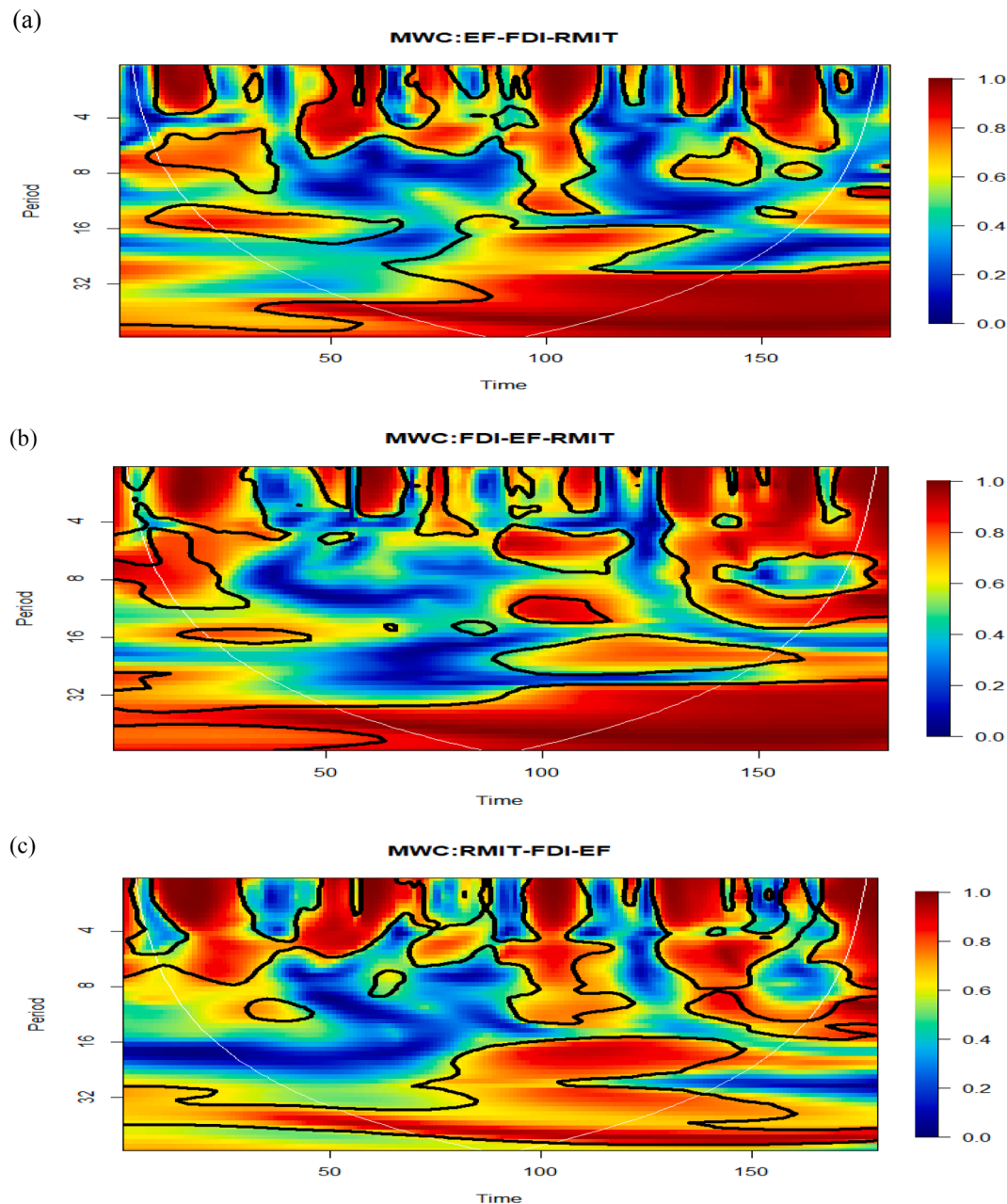


Fig. 11. Multiple wavelet coherence.

the red and green lines during the three intervals (0-1 shows long-term, 1-2 indicates medium-term, and 2-3 exhibits short-term causal link) and rejects the null hypothesis (i.e., there is not causal association between dependent and independent series). Besides, the red and green lines represent the 5 % & 10 % significance level, respectively. For instance, Fig. 12 reports that FDI significantly granger causes the EF in Pakistan at 5 % significance level only in the long-run since the blue line is over the red and green lines during the first interval. The outcome rejects the null hypothesis and implies that any policy change in FDI by the authorities of Pakistan will cause to a change in EF. It means that EF is significantly sensitive to FDI and this nexus provides several implications for the pertinent authorities.

In a similar vein, Fig. 13 reports the significant causal nexus of RMIT with EF which runs from RMIT to EF. Such causal link remains significant during the long-term and short-term at 5 % significance level. It indicates that any policy shock by Pakistan authorities to RMIT can bring a significant shock in the ratio of EF. Like FDI, RMIT also has the

sensitive causal link with EF in Pakistan. To recapitulate, the causality tests' outcome suggests that Pakistani authorities should consider the sensitive response of EF while implementing the any policy change in FDI and RMIT.

#### Conclusion and policy recommendations

The current study, for the first time, presents the wavelet analysis to divulge the asymmetric association between foreign direct investment (FDI), foreign remittances inflow (RMIT) and ecological footprint (EF) for Pakistan. To do so, the article utilizes the quarterly data from 1976Q1 to 2020Q4. The results of all family's members of wavelet coherence approach affirm that: (i) FDI significantly predicts the EF, (ii) likewise, RMIT determine the ratio of EF, (iii) and we find a notable link between FDI and RMIT to recommend the suitable policies.



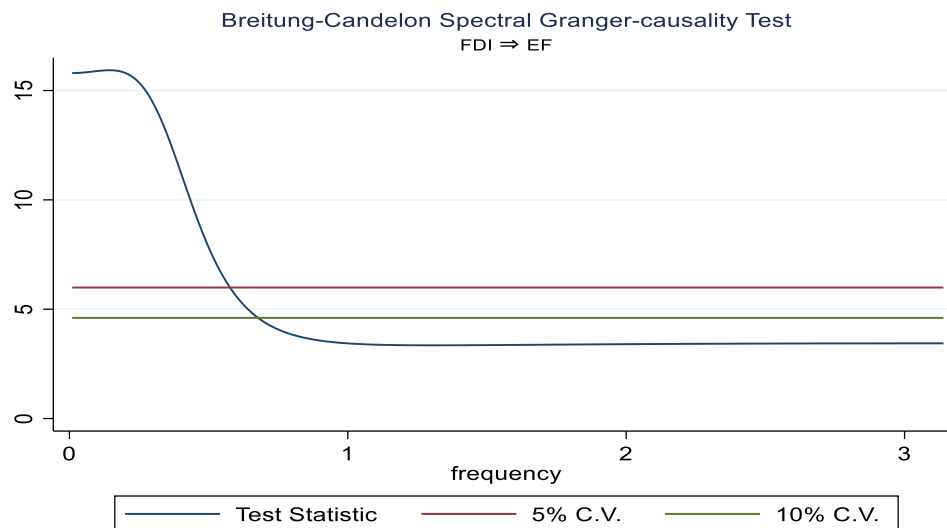


Fig. 12. Spectral Breitung-Candelon causality from FDI to EF.

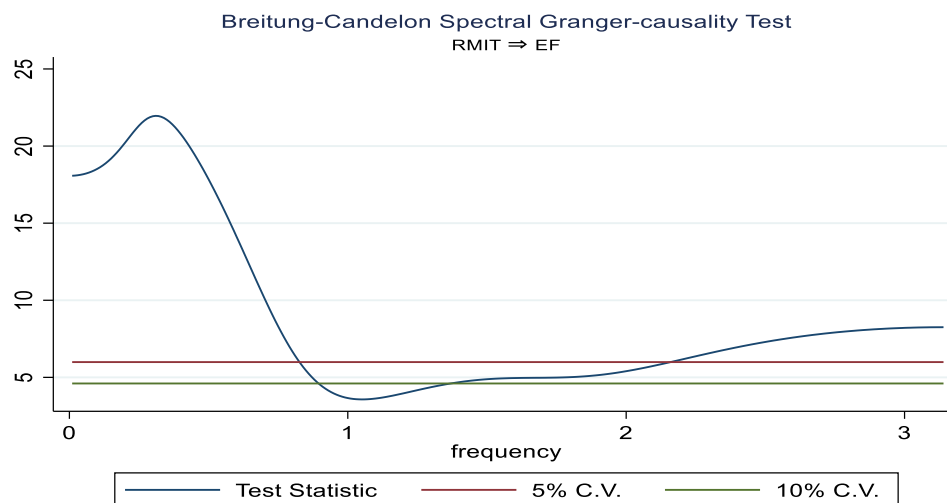


Fig. 13. Spectral Breitung-Candelon causality from RMIT to EF.

### Core policy framework

Considering the outcome of wavelet coherence approach, the following policies can be recommended for Pakistan. Firstly, the outcome of wavelet coherence and frequency domain causality test affirm that the variations in EF is highly sensitive to the changes in FDI. Further, the results indicate that the upward trends in FDI leads to intensify the issue of environmental degradation by increasing EF in all time periods. This inference has several important implications. For example, Pakistan is enjoying a bulk of FDI under the umbrella of China-Pakistan Economic Corridor (CPEC). Also, several other companies invest in Pakistan during different periods. The rise in environmental pollution due to FDI inflows indicates the Pakistani authorities compromise in the context of green environment rule and regulation. Therefore, FDI shows positive effects on EF. In this context, Pakistan government should take the serious measures in orders to practice the environmental related regulations. Pakistani authorities can adopt the following phase-wise green FDI policy. In the first phase, the Pakistani authorities should invite the foreign firms that are practicing the green technology methods to invest in Pakistan through cutting the tax ratio. At this stage, the Pakistani government should not rush in imposing the taxes on the foreign firms that use the cheap energy for production. Otherwise, the FDI ratio may significantly decline. Such step will

escalate the green FDI level in Pakistan. In the second phase, once a significant rise in green FDI is recorded; now the Pakistani policy makers should commence to impose the taxes on the foreign firms that use the cheap energy for production while gradually increasing the tax ratio. In the third phase, the Pakistani authorities should proceed towards the net green FDI by imposing high tax ratios on the cheap technology-based foreign firms and deploying the taxes as a subsidy for green FDI. This process may significantly contribute in triggering the green FDI inflows in Pakistan.

Secondly, we also observe that RMIT also triggers the EF that results in environmental pollution. Since RMIT increase the household's income that leads to increase the demand; ultimately, the producers use cheap production methods in order to supply the required demand in the market; such process leads to cause the environmental degradation. Also, RMIT increases the saving that enhances the investment and production process. Since Pakistan is practicing flexible green environmental regulation; hence, it results in increasing pollution. To handle this situation, Pakistani government should adopt the green measures for consumption and production sides. For consumption side, the authorities should do aware the consumers regarding the importance of green environment and similarly to usage of green product. This practice will help in reducing the consumption of the goods produced by using the conventional energy and increasing the green goods produced by

deploying the clean energy. For production side, the Pakistani authorities should impose the tight green environment policy by imposing the green taxes on the firms use the conventional energy for production purpose. On the other hand, the producers using the green technologies should be appreciated by providing the substantial green subsidies in order to boost the green products' process. Ultimately, such measure may help in promoting the green and sustainable development in Pakistan, and other developing and emerging economies as well.

The recent study possesses some limitation that can be considered for future research insights. Firstly, the study mainly focuses on Pakistan, the literature can be extended in future by deploying the same model and methods for the other economies and regions such as Asia, Europe, South Africa. Secondly, the model of current study can be extended by including some other series such as exchange rate, globalization, economic globalization, global value chain etc. in order to get more interesting findings. Lastly, the researchers can use multiple proxies for environmental pollution for more detailed, informative, and comparative results.

#### CRediT authorship contribution statement

**Muhammad Zubair Chishti:** Conceptualization, Methodology, Software, Data curation, Writing – original draft, Software, Visualization, Investigation.

#### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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#### References

- Abbass, K., Song, H., Mushtaq, Z., & Khan, F. (2022). Does technology innovation matter for environmental pollution? Testing the pollution halo/haven hypothesis for Asian countries. *Environmental Science and Pollution Research*, 1–19.
- Abdoul, M., & Hammami, S. (2017). Investigating the causality links between environmental quality, foreign direct investment and economic growth in MENA countries. *International Business Review*, 26, 264–278. <https://doi.org/10.1016/j.ibusrev.2016.07.004>
- Adeel-Farooq, R. M., Riaz, M. F., & Ali, T. (2021). Improving the environment begins at home: Revisiting the links between FDI and environment. *Energy*, 215, Article 119150.
- Ahmad, W., Ozturk, I., & Majeed, M. T. (2022). How do remittances affect environmental sustainability in Pakistan? Evidence from NARDL approach. *Energy*, 243, Article 122726.
- Ahmed, Z., Ahmad, M., Rjoub, H., Kalugina, O. A., & Hussain, N. (2022). Economic growth, renewable energy consumption, and ecological footprint: Exploring the role of environmental regulations and democracy in sustainable development. *Sustainable Development*, 30(4), 595–605.
- Ali, M., Kirikkaleli, D., Sharma, R., & Altuntaş, M. (2022). The nexus between remittances, natural resources, technological innovation, economic growth, and environmental sustainability in Pakistan. *Environmental Science and Pollution Research*, 1–19.
- Al-mulali, U. (2012). Factors affecting CO2 emission in the Middle East: A panel data analysis. *Energy*, 44(1), 564–569.
- Alola, A. A., Yalciner, K., Alola, U. V., & Saint Akadiri, S. (2019). The role of renewable energy, immigration and real income in environmental sustainability target. Evidence from Europe largest states. *Science of The Total Environment*, 674, 307–315.
- Ansari, M. A. (2022). Re-visiting the Environmental Kuznets curve for ASEAN: A comparison between ecological footprint and carbon dioxide emissions. *Renewable and Sustainable Energy Reviews*, 168, Article 112867.
- Arif, U., Arif, A., & Khan, F. N. (2022). Environmental impacts of FDI: Evidence from heterogeneous panel methods. *Environmental Science and Pollution Research*, 29(16), 23639–23649.
- Ayeche, M. B., Barhoumi, M., & Amin, M. (2016). Causal linkage between economic growth, financial development, trade openness and CO2 emissions in European Countries. *American Journal of Environmental Engineering*, 6, 110–122.
- Breitung, J., & Candelon, B. (2006). Testing for short-and long-run causality: A frequency-domain approach. *Journal of Economics*, 132(2), 363–378. <https://doi.org/10.1016/j.jeconom.2005.02.004>
- Brown, L., McFarlane, A., Campbell, K., & Das, A. (2020). Remittances and CO2 emissions in Jamaica: An asymmetric modified environmental kuznets curve. *The Journal of Economic Asymmetries*, 22, e00166.
- Bulus, G. C., & Koc, S. (2021). The effects of FDI and government expenditures on environmental pollution in Korea: The pollution haven hypothesis revisited. *Environmental Science and Pollution Research*, 28, 38238–38253. <https://doi.org/10.1007/s11356-021-13462-z>
- Caglar, A. E., Yavuz, E., Mert, M., & Kilic, E. (2022). The ecological footprint facing asymmetric natural resources challenges: Evidence from the USA. *Environmental Science and Pollution Research*, 29(7), 10521–10534.
- Cazachevici, A., Havranek, T., & Horvath, R. (2020). Remittances and economic growth: A meta-analysis. *World Development*, 134, Article 105021.
- Chen, J., Tan, H., & Ma, Y. (2022). Distinguishing the complex effects of foreign direct investment on environmental pollution: Evidence from China. *The Energy Journal*, 43(4).
- Chishti, M. Z., & Dogan, E. (2022). Analyzing the determinants of renewable energy: The moderating role of technology and macroeconomic uncertainty. *Energy & Environment*, 0958305X221137567.
- Chishti, M. Z., & Sinha, A. (2022). Do the shocks in technological and financial innovation influence the environmental quality? Evidence from BRICS economies. *Technology in Society*, 68, Article 101828.
- Chishti, M. Z., Ahmad, M., Rehman, A., & Khan, M. K. (2021a). Mitigations pathways towards sustainable development: Assessing the influence of fiscal and monetary policies on carbon emissions in BRICS economies. *Journal of Cleaner Production*, 292, Article 126035.
- Chishti, M. Z., Ahmed, Z., Murshed, M., Namkambe, H. H., & Ulucak, R. (2021b). The asymmetric associations between foreign direct investment inflows, terrorism, CO2 emissions, and economic growth: A tale of two shocks. *Environmental Science and Pollution Research*, 1–19.
- Chishti, M. Z., Iqbal, J., Mahmood, F., & Azeem, H. S. M. (2020a). The implication of the oscillations in exchange rate for the commodity-wise trade flows between Pakistan and China: An evidence from ARDL approach. *Review of Pacific Basin Financial Markets and Policies*, 23(04), 2050030.
- Chishti, M. Z., Ullah, S., Ozturk, I., & Usman, A. (2020b). Examining the asymmetric effects of globalization and tourism on pollution emissions in South Asia. *Environmental Science and Pollution Research*, 27(22), 27721–27737.
- Cil, N. (2022). Re-examination of pollution haven hypothesis for Turkey with Fourier approach. *Environmental Science and Pollution Research*, 1–13.
- Cole, M. A., Elliott, R. J., & Zhang, J. (2011). Growth, foreign direct investment, and the environment: Evidence from Chinese cities. *Journal of Regional Science*, 51(1), 121–138.
- Demena, B. A., & Afesorgbor, S. K. (2020). The effect of FDI on environmental emissions: Evidence from a meta-analysis. *Energy Policy*, 138, Article 111192.
- Dogan, E., Chishti, M. Z., Alavijeh, N. K., & Tzeremes, P. (2022). The roles of technology and Kyoto Protocol in energy transition towards COP26 targets: Evidence from the novel GMM-PVAR approach for G-7 countries. *Technological Forecasting and Social Change*, 181, Article 121756.
- Duodu, E., Oteng-Abayie, E. F., Frimpong, P. B., & Takyi, P. O. (2022). The impact of the Compact with Africa initiative on foreign direct investments and environmental pollution. *Management of Environmental Quality: An International Journal*, (ahead-of-print).
- Fahad, S., Bai, D., Liu, L., & Baloch, Z. A. (2022). Heterogeneous impacts of environmental regulation on foreign direct investment: Do environmental regulation affect FDI decisions? *Environmental Science and Pollution Research*, 29(4), 5092–5104.
- Golub, S.S., Kauffmann, C., Yeres, P., 2011. Defining and Measuring Green FDI. Organization for Economic Development and Cooperation Working paper 2011/102.
- Goodell, J. W., & Goutte, S. (2020). Co-movement of COVID-19 and Bitcoin: Evidence from wavelet coherence analysis. *Journal of Corporate Finance Research Letters*. <https://doi.org/10.1016/j.frl.2020.101625>
- Habib, Y., Xia, E., Fareed, Z., & Hashmi, S. H. (2021). Time-frequency co-movement between COVID-19, crude oil prices, and atmospheric CO2 emissions: Fresh global insights from partial and multiple coherence approach. *Environment, Development and Sustainability*, 23(6), 9397–9417.
- Harding, T., & Javorcik, B. S. (2011). Roll out the red carpet and they will come: Investment promotion and FDI inflows. *Economic Journal*, 121(557), 1445–1476.
- Hitam, M. B., & Borhan, H. B. (2012). FDI, growth and the environment: Impact on quality of life in Malaysia. *Procedia - Social and Behavioral Sciences*, 50, 333–342. <https://doi.org/10.1016/j.sbspro.2012.08.038>
- Huang, Y., Haseeb, M., Usman, M., & Ozturk, I. (2022). Dynamic association between ICT, renewable energy, economic complexity and ecological footprint: Is there any difference between E-7 (developing) and G-7 (developed) countries? *Technology in Society*, 68, Article 101853.
- Islam, M. (2022). Do personal remittances cause environmental pollution? Evidence from the top eight remittance-receiving countries. *Environmental Science and Pollution Research*, 29(24), 35768–35779.
- Jafri, M. A. H., Abbas, S., Abbas, S. M. Y., & Ullah, S. (2022). Caring for the environment: Measuring the dynamic impact of remittances and FDI on CO2 emissions in China. *Environmental Science and Pollution Research*, 29(6), 9164–9172.
- Jahanger, A., Chishti, M. Z., Joshua Chukwuma, O., & Awan, A. (2022). How far renewable energy and globalization are useful to mitigate the environment in Mexico? Application of QARDL and spectral causality analysis. *Renewable Energy*.

- Jahanger, A., Yu, Y., Awan, A., Chishti, M. Z., Radulescu, M., & Balsalobre-Lorente, D. (2022). The impact of hydropower energy in Malaysia under the EKC hypothesis: Evidence from quantile ARDL approach. *SAGE Open*, 12(3), 21582440221109580.
- Jamil, K., Liu, D., Gul, R. F., Hussain, Z., Mohsin, M., Qin, G., & Khan, F. U. (2021). Do remittance and renewable energy affect CO2 emissions? An empirical evidence from selected G-20 countries. *E & E*, 0958305X211029636.
- Johansen, S., & Juselius, K. (1990). Maximum likelihood estimation and inference on cointegration – with applications to the demand for money. *Oxford Bulletin of Economics and Statistics*, 52(2), 169–210.
- Kearsley, A., & Riddel, M. (2010). A further inquiry into the pollution haven hypothesis and the Environmental Kuznets curve. *Ecological Economics*, 69(4), 905–919.
- Khan, A., Chenggang, Y., Hussain, J., & Bano, S. (2019). Does energy consumption, financial development, and investment contribute to ecological footprints in BRI regions? *Environmental Science and Pollution Research*, 26, 36952–36966. <https://doi.org/10.1007/s11356-019-06772-w>
- Lau, L. S., Choong, C. K., & Eng, Y. K. (2014). Investigation of the environmental Kuznets curve for carbon emissions in Malaysia: DO foreign direct investment and trade matter? *Energy Policy*, 68, 490–497. <https://doi.org/10.1016/j.enpol.2014.01.002>
- Li, X., & Fu, H. (2022). Migrant remittance, agricultural producer services, and environmental pollution. *Asia-Pacific Journal of Accounting & Economics*, 29(5), 1267–1282.
- Liu, H., Alharthi, M., Zafar, M. W., Tahir, M. S., & Asghar, M. M. (2022). Understanding the role of technology in Asian economies: The environmental impact of remittances and economic complexity. *Evaluation Review*, 0193841X221120483.
- Liu, Y., Sadiq, F., Ali, W., & Kumail, T. (2022). Does tourism development, energy consumption, trade openness and economic growth matters for ecological footprint: Testing the Environmental Kuznets Curve and pollution haven hypothesis for Pakistan. *Energy*, 245, Article 123208.
- Ahmad, M., Haq, Z. U., Khan, Z., Khattak, S. I., Rahman, Z. U., & Khan, S. (2019). Does the inflow of remittances cause environmental degradation? Empirical evidence from China. *Economic Research-Ekonomika Istraživanja*, 32(1), 2099–2121. <https://doi.org/10.1080/1331677X.2019.1642783>
- Meyer, D., & SHERA, A. (2017). The impact of remittances on economic growth: An econometric model. *Economia*, 18(2), 147–155. <https://doi.org/10.1016/j.econ.2016.06.001>
- Mishra, S., Sharif, A., Khuntia, S., Meo, S. A., & Khan, S. A. R. (2019). Does oil price impede Islamic stock indices? Fresh insights from wavelet-based quantile-on-quantile approach. *Resources Policy*, 62, 292–304.
- Motelle, S. I. (2011). The role of remittances in financial development in Lesotho: Evidence from alternative measures of financial development. *Journal of Development and Agricultural Economics*, 241–251.
- Mujtaba, G., & Ashfaq, S. (2022). The impact of environment degrading factors and remittances on health expenditure: An asymmetric ARDL and dynamic simulated ARDL approach. *Environmental Science and Pollution Research*, 29(6), 8560–8576.
- Musah, M., Mensah, I. A., Alfred, M., Mahmood, H., Murshed, M., Omari-Sasu, A. Y., et al. (2022). Reinvesting the pollution haven hypothesis: The nexus between foreign direct investments and environmental quality in G-20 countries. *Environmental Science and Pollution Research*, 29(21), 31330–31347.
- Neog, Y., & Yadava, A. K. (2020). Nexus among CO2 emissions, remittances, and financial development: A NARDL approach for India. *Environmental Science and Pollution Research*, 27, 44470–44481. <https://doi.org/10.1007/s11356-020-10198-0>
- Nhuong, B. H., & Quang, P. T. (2022). Are FDI inflows crucial for environmental protection in various Asian regions? *Journal of Environmental Assessment Policy and Management*, 2250028.
- Noureen, S., Iqbal, J., & Chishti, M. Z. (2022). Exploring the dynamic effects of shocks in monetary and fiscal policies on the environment of developing economies: Evidence from the CS-ARDL approach. *Environmental Science and Pollution Research*, 29, 45665–45682. <https://doi.org/10.1007/s11356-022-19095-0>
- Nwani, C., Alola, A. A., Omoke, C. P., et al. (2022). Responding to the environmental effects of remittances and trade liberalization in net-importing economies: The role of renewable energy in Sub-Saharan Africa. *Economic Change and Restructuring*. <https://doi.org/10.1007/s10644-022-09403-6>
- Pao, H.-T., & Tsai, C.-M. (2011). Multivariate granger causality between CO2 emissions, energy consumption, FDI (foreign direct investment) and GDP (gross domestic product): Evidence from a panel of BRIC (Brazil, Russian federation, India, and China) countries. *Energy*, 36(1), 685–693.
- Paramati, S. R., Ummalla, M., & Apergis, N. (2016). The effect of foreign direct investment and stock market growth on clean energy use across a panel of emerging market economies. *Energy Economics*, 56, 29–41. <https://doi.org/10.1016/j.eneco.2016.02.008>
- Pazienza, P. (2015). The relationship between CO2 and foreign direct investment in the agriculture and fishing sector of OECD countries: Evidence and policy considerations. *Intellectual Economics*, 9(1), 55–66.
- Percival, D. B., & Walden, A. T. (2000). *Wavelet methods for time series analysis*. Cambridge: Cambridge University Press.
- Polloni-Silva, E., Roiz, G. A., Mariano, E. B., Morales, H. F., & Rebelatto, D. A. N. (2022). The environmental cost of attracting FDI: An empirical investigation in Brazil. *Sustainability*, 14(8), 4490.
- Rafique, M. Z., Li, Y., Larik, A. R., & Monaheng, M. P. (2020). The effects of FDI, technological innovation, and financial development on CO2 emissions: Evidence from the BRICS countries. *Environmental Science and Pollution Research*, 27(19), 23899–23913.
- Rehman, A., Ma, H., Ahmad, M., Ozturk, I., & Chishti, M. Z. (2021a). How do climatic change, cereal crops and livestock production interact with carbon emissions? Updated evidence from China. *Environmental Science and Pollution Research*, 1–12.
- Rehman, A., Ma, H., Chishti, M. Z., Ozturk, I., Irfan, M., & Ahmad, M. (2021b). Asymmetric investigation to track the effect of urbanization, energy utilization, fossil fuel energy and CO2 emission on economic efficiency in China: Another outlook. *Environmental Science and Pollution Research*, 28(14), 17319–17330.
- Ren, S., Yuan, B., Ma, X., & Chen, X. (2014). International trade, FDI (foreign direct investment) and embodied CO2 emissions: A case study of Chinas industrial sectors. *China Economic Review*, 28, 123–134. <https://doi.org/10.1016/j.chieco.2014.01.003>
- Salam, M., & Chishti, M. Z. (2022). Will ASEAN countries be a potential choice for the export of pollution intensive goods? *Environmental Science and Pollution Research*. <https://doi.org/10.1007/s11356-022-21427-z>
- Shahbaz, M., Nasir, M. A., & Roubaud, D. (2018). Environmental degradation in France: The effects of FDI, financial development, and energy innovations. *Energy Economics*, 74, 843–857. <https://doi.org/10.1016/j.eneco.2018.07.020>
- Shahbaz, M., Nasreen, S., Abbas, F., & Anis, O. (2015). Does foreign direct investment impede environmental quality in high-, middle-, and low-income countries? *Energy Economics*, 51, 275–287. <https://doi.org/10.1016/j.eneco.2015.06.014>
- Sharif, A., Meo, M. S., Chowdhury, M. A. F., & Sohag, K. (2021). Role of solar energy in reducing ecological footprints: An empirical analysis. *Journal of Cleaner Production*, 292, Article 126028.
- Sharma, K., Bhattarai, B., & Ahmed, S. (2019). Aid, growth, remittances and carbon emissions in Nepal. *Energy Journal*, 40. <https://doi.org/10.5547/01956574.40.1.ksha>
- Solarin, S. A., Al-Mulali, U., Musah, I., & Ozturk, I. (2017). Investigating the pollution haven hypothesis in Ghana: An empirical investigation. *Energy*, 124, 706–719. <https://doi.org/10.1016/j.energy.2017.02.089>
- State Bank of Pakistan, 2021. <https://www.sbp.org.pk/>.
- Tang, J. (2015). Testing the pollution haven effect: Does the type of FDI matter? *Environmental and Resource Economics*, 60, 549–578. <https://doi.org/10.1007/s10640-014-9779-7>
- Ullah, S., Chishti, M. Z., & Majeed, M. T. (2020). The asymmetric effects of oil price changes on environmental pollution: Evidence from the top ten carbon emitters. *Environmental Science and Pollution Research*, 27, 29623–29635.
- Ullah, S., Majeed, M. T., & Chishti, M. Z. (2020). Examining the asymmetric effects of fiscal policy instruments on environmental quality in Asian economies. *Environmental Science and Pollution Research*, 27(30), 38287–38299.
- Usman, M., & Jahanger, A. (2021). Heterogeneous effects of remittances and institutional quality in reducing environmental deficit in the presence of EKC hypothesis: A global study with the application of panel quantile regression. *Environmental Science and Pollution Research*, 28, 37292–37310. <https://doi.org/10.1007/s11356-021-13216-x>
- Usman, A., Ullah, S., Ozturk, I., Chishti, M. Z., & Zafar, S. M. (2020). Analysis of asymmetries in the nexus among clean energy and environmental quality in Pakistan. *Environmental Science and Pollution Research*, 27(17), 20736–20747.
- Vackář, D. (2012). Ecological footprint, environmental performance and biodiversity: A cross-national comparison. *Ecological Indicators*, 16, 40–46.
- Weimin, Z., & Zubair Chishti, M. (2021). Toward sustainable development: assessing the effects of commercial policies on consumption and production-based carbon emissions in developing economies. *SAGE Open*, 11(4), 21582440211061580.
- Weimin, Z., Chishti, M. Z., Rehman, A., & Ahmad, M. (2021). A pathway toward future sustainability: assessing the influence of innovation shocks on CO2 emissions in developing economies. *Environment, Development and Sustainability*, 1–24.
- Yakubu, I. N., Kapusuzoglu, A., & Ceylan, N. B. (2022). Investigating the Role of Export Diversification, Remittances, and Environmental Sustainability in Accordance with Clean Energy and Zero Emission. In *Circular Economy and the Energy Market* (pp. 51–65). Cham: Springer.
- Yang, B., Jahanger, A., Usman, M., & Khan, M. A. (2021). The dynamic linkage between globalization, financial development, energy utilization, and environmental sustainability in GCC countries. *Environmental Science and Pollution Research*, 1–21. <https://doi.org/10.1007/s11356-020-11576-4>
- Zafar, M. W., Saleem, M. M., Destek, M. A., & Caglar, A. E. (2022). The dynamic linkage between remittances, export diversification, education, renewable energy consumption, economic growth, and CO2 emissions in top remittance-receiving countries. *Sustainable Development*, 30(1), 165–175.
- Zhang, C., & Zhou, X. (2016). Does foreign direct investment lead to lower CO2 emissions? Evidence from a regional analysis in China. *Renewable and Sustainable Energy Reviews*, 58, 943–951.
- Zhao, L., Shao, K., & Ye, J. (2022). The impact of fiscal decentralization on environmental pollution and the transmission mechanism based on promotion incentive perspective. *Environmental Science and Pollution Research*, 1–17.