# Tourism, Environment and Energy: An Analysis for China

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# Tourism, Environment and Energy: An Analysis for China

**Abstract:** International tourism as a cause of global warming is a controversial and topical issue. Here, we use the novel Morlet wavelet time-frequency approach to gain insight into the dynamic nexus between tourism, renewable energy consumption, energy consumption and carbon dioxide emissions for China using annual data over the period 1974-2016. The techniques we use include continuous wavelet power spectrum, the wavelet coherency, and the partial and the multiple wavelet coherence for time-frequency decomposition that can capture local oscillatory components in time series. Our findings support the hypothesis that tourism can cause increased energy consumption and carbon dioxide emissions in China, which challenges the sustainable tourism development goal. However, on the positive side, the relationship between tourism and renewable energy consumption is shown to facilitate reduced environmental degradation in the medium-long run.

**Keywords:** Energy consumption; renewable energy; $CO_2$ emission; tourism; partial and multiple wavelet coherence; country study

**JEL:** Q32; Q35; Q53; Z30; Z32

## 1. Introduction

On one hand, international tourism is seen as an important engine for generating growth and employment in developing countries. On the other hand, it is seen as a contributor to global warming particularly with regard to the carbon dioxide ($CO_2$) emissions from aircraft, cruise ships and accommodation construction. Tourism is estimated to account for 5% of global carbon emissions (Solarin, 2014; and Othman, Mohamed, & Aziz, 2012). We need to be careful about concluding that a simple trade off exists here. During the earlier stages of economic growth, nations rely more on fossil fuel-based energy solutions, as this energy solution is cost effective. However, the fossil fuel-driven growth trajectory results in ambient air pollution through greenhouse gas emissions, of which $CO_2$ holds a major share. Gradual rise in this emission level poses a threat before the hygienic state of the labour force, and thereby, jeopardizing the growth trajectory. In order to sustain the economic growth, the nations need to retain the environmental quality, and in pursuit of retaining environmental quality, policymakers start investing in renewable energy projects. Hence, the objective of sustainable economic growth puts a country in a strong position to invest in renewable energy projects. To gain insights into this complex issue, our paper, using China as a case study, explores the dynamic association between the following variables: tourism, renewable energy consumption, fossil fuel energy consumption, and $CO_2$ emissions. With China, its vast tourism industry and substantial effect on global warming, makes it an obvious choice. Since the relationship between these variables is complex and ambiguous, we take the Morlet wavelet time-frequency approach. This allows us to look for evidence of a causal relationship between tourism demand and $CO_2$ emissions, and, to explore the mitigating effects of renewable energy.

The Chinese tourist industry has rapidly expanded since the economic reform in the late seventies. According to the World Travel and Tourism Council Report (WTTC, 2018), China ranks second after the United States in terms of the size of travel and tourism, as a contributor to GDP. During 2017, this sector contributed US$402.3 billion directly to Chinese GDP, it generated 28,250,000 jobs and it is predicted that the employment in the tourism sector will grow by 1.5% in 2018, with international tourist arrivals expected to be 63,539,000. The growth prospects for the tourism industry are very strong with a forecasted increase of 1.8% per annum in the upcoming ten years (WTTC, 2018). With the increase in China's tourism and the use of energy by this sector, its impact on the environment is a matter for concern. Shuxin, Genxu, & Yiping (2016) show that tourism-induced energy consumption in China has increased from 178.21 PJ to 565.82 PJ between 1994-2013, and during the same period, the $CO_2$ emissions from tourism-induced transport have increased from 14.96 Mt to 47.94 Mt. This increase has been attributed to the rise in per-person distance for every trip, along with the number of trips. Using carbon-input-output table, Tang and Ge (2018) show that the carbon footprint of tourism in China is more than 20 per cent of the total $CO_2$ emissions.[2] Using the similar methodological approach, Li, Li, Tang, & Wang (2019) have estimated the nearly 39 per cent of the $CO_2$ emissions from transport sector is caused by tourism-related activities. In 2012, 25.70 per cent of the total $CO_2$ emissions in Beijing were caused by tourism-related activities (Beijing Municipal Bureau of Statistics, 2014). Wu and Shi (2011) state that energy use and its impact on the environment increase synchronously with China's growing tourism. To accomplish the strategic objective of environmental sustainability along with tourism development, it is important to follow the strategic paths which respect the environment as well as ensure optimal economic

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[2] We have considered the estimations of different researchers, as China Energy Statistics Yearbook does not contain any particular information on tourism-induced energy use (see Tang et al., 2014; Chen, Thapa, & Yan, 2018).

benefits from tourism. Gössling, Scott, and Hall (2013) argue that all sectors, including tourism, need strong mitigation for the associated greenhouse gas emissions (GHG) so as to achieve the objective of reducing global emissions by 80% from the current level by 2050.

The search for cheap and secure energy sources by the developed and energy dependent countries has raised the demand for alternative energy sources (alternatives to fossil fuels) for dealing with global warming and GHG emissions. The role of renewable energy in sustainable energy supply and reductions of carbon emissions has been widely acknowledged in the last ten years (Ocal & Aslan, 2013). The threat of extinction of fossil fuels and increasing concerns regarding $CO_2$ emissions and global warming have helped in the emergence of renewable energy sources. Renewable energy is the fastest growing source of energy in the world, its consumption has been increasing at an average of 2.3% per year since 2015 and this is expected to continue until 2040 (EIA, 2017). This increase in consumption of renewable energy sources includes wind energy, biomass energy, hydropower energy, waste energy and geo-thermal energy. China has started adopting the strategy of using renewable energy for dealing with issues of climate change and sustainable energy supply and is becoming a leading investor in this sector.

This study examines the dynamic connection between tourism, renewable and fossil fuel energy consumption, and $CO_2$ emanations for ascertaining sustainable tourism development in China. Over the years, China is gradually turning out to be a popular tourism destination in the globe, and in order to facilitate the tourism in China, policymakers are relying on the transport sector. Now, this sector is largely dependent on the fossil fuel-based energy solutions, and the environmental degradation caused by the tourism activities is largely caused by the transport sector only. In terms of $CO_2$ emissions from tourism, China stands second in the world (Lenzen et al., 2018). In a recent study carried out on Yangtze River Delta, it has been seen that the tourism-related energy consumption has increased by 3.57 times and tourism-borne $CO_2$ emissions have increased by 3.19 times between 2001 and 2015 (Chen, Thapa, & Yan, 2018). Moreover, emergence of ecotourism in China, the country is experiencing faster depletion of natural resources, and this situation can be attributed to the existing transportation architecture (UNEP, 2008). These concerns gradually diminished the acceptability of fossil fuel based energy solutions and increased the demand of renewable energy solutions in the tourism sector in China. Owing to this scenario, 13th Five-Year Plan for Tourism Development of Beijing is focused at promoting clean energy-driven vehicles for the purpose of tourism (UNWTO, 2018). Because of these developments in China, this study aims to assess the association between tourism, renewable and fossil fuel energy consumption, and $CO_2$ emanations in China.

Following Aguiar-Conraria, Azevedo, and Soares (2008) and Aguiar-Conraria, and Soares (2011), we investigate the dynamic associations by applying innovative continuous wavelet power spectrum and wavelet coherence techniques, which decompose time-frequencies of the variables being studied. Also, using the wavelet tools, we identify the changes both over time and differences across frequencies in tourism and energy variables within a unified framework. The wavelet power spectrum, in particular, can be easily adapted to consider the time-varying features at each periodic component that has not been apprehended so far. Besides, we employ partial and multiple wavelet coherence techniques to assess the association among the model parameters. These techniques assess the wavelet coherence across diverse temporal domains subsequent to adjusting conjoint factors and explanatory power of model parameters (Ng & Chan, 2012). Owing to the convolution of the association, partial and multiple wavelet coherence techniques can advocate comprehensive conclusions concerning the associations in the frequency domain.

Our study contributes to the literature of tourism economics through several dimensions: (a) considering the sustainable tourism in China, this study bring together the perspective of sustainable energy and environmental policies, which has hardly been considered in the literature, (b) the association between tourism, renewable and fossil fuel energy consumption, and $CO_2$ emission has been analyzed in the frequency domain by localized oscillatory components in the time-frequency area (Aguiar-Conraria et al., 2008), and thereby, overriding the shortcomings of the traditional time series analysis, (c) the choice of Morlet wavelet enables us to harvest "information on the amplitude and phase, both essential to study synchronism between different time-series" (Aguiar-Conraria & Soares, p. 648, 2011), and (d) by means of the lead-lag movement divulged through wavelet analysis, we are able to analyse the trajectory of the associative movement among the model parameters.

The remainder of the paper is set out as follows. The next section elaborates on the existing literature. The third section explains the model framework and data. The fourth section discusses the results and findings. The final section concludes with a discussion of policy implications.

## 2. Literature Review

The existing empirical literature on $CO_2$ emission and economic development finds an association between $CO_2$ emission, economic growth and energy consumption (Aslanidis & Iranzo, 2009; Apergis & Payne, 2010; Ozturk, 2010; Shahbaz & Sinha, 2019). On the other hand, world-wide tourism has enjoyed an above-average growth rate, at around 4% per year, for the last eight straight years (UNWTO, 2017). Obviously, it has the potential to substantially increase energy consumption and $CO_2$ emission. However, the actual effect upon global warming is going to be critically dependent upon the use of renewable energy; hence this literature is also discussed below.

### *2.1. Carbon dioxide emissions and non-renewable energy consumption*

Non-renewable energy consumption is considered one of the most vital determinants of $CO_2$ emissions. Several studies investigate the relationship between non-renewable energy consumption and $CO_2$ emissions. For instance, Say and Yucel (2006) find a significantly positive relationship between energy consumption and $CO_2$ emissions in Turkey. Jalil and Mahmoud (2009) examine the relationship between energy consumption, income, trade openness and $CO_2$ emissions in China during 1975-2005 and find a similar story. Various studies confirm this positive relationship between energy consumption and $CO_2$ emissions such as Apergis and Payne (2009), Niu, Ding, Niu, Li, and Luo (2011), Jayanthakumaran, Verma, and Y. Liu (2012), Shahbaz, Khraief, Uddin, and Ozturk (2014), Tang and Tan (2015), Ibrahiem (2016), and Riti, Song, Shu and Kamah (2017).

Several studies that investigate the causal relationship between energy consumption and $CO_2$ emissions find inconclusive results. Some finds a bidirectional causal relationship such as Apergis and Payne (2009), Alam, Begum, Buysse, Rahman, and Huylenbroeck et al. (2011), and Shahbaz, Farhani, and Ozturk (2015). In contrast, other studies find a unidirectional causal relationship from energy consumption to $CO_2$ emissions such as Zeshan and Ahmed (2013), Alshehry and Belloumi (2015), and Shahzad, Kumar, Zakaria and Hurr (2017). In addition, a unidirectional causal relationship from $CO_2$ emissions to energy consumption is found in other studies as such Lean and Smyth (2010).

### *2.2. Carbon dioxide emissions and renewable energy consumption*

Some of the literature, for example Sebri and Ben-Salha (2014) focus on renewable energy consumption as an important determinant that can mitigate greenhouse gas emissions and $CO_2$ emissions in particular. Most of these studies examine the relationship between $CO_2$ emissions and renewable energy consumption and conclude that a negative relationship holds, i.e. an increase in renewable energy consumption reduces $CO_2$ emissions; notably: Chiu and Chang (2009), Bilgili, Koçak, and Bulut (2016), Zoundi (2017), and Álvarez-Herranz, Balsalobre-Lorente, Cantos, and Shahbaz (2017). However, some of this literature finds mixed results such as Sebri and Ben-Salha (2014). Some other studies examine the relationship between renewable energy consumption, non-renewable energy consumption and $CO_2$ emissions. Al-Mulali Fereidouni, and Mohammed (2015) examines the relationships between renewable electricity consumption, non-renewable electricity consumption, capital, labour, exports, imports and $CO_2$ emissions in Vietnam for the period 1981-2011 and finds that non-renewable electricity consumption contributes to $CO_2$ emissions while renewable electricity consumption has no effect on it. Ben-Jebli and Ben-Youssef (2015) in Tunisia find a positive relationship between non-renewable energy consumption and $CO_2$ emissions and a negative relationship between renewable energy consumption and $CO_2$ emissions. Dogan and Seker (2016) investigate the relationship between renewable energy consumption, non-renewable energy consumption, trade openness, real income and $CO_2$ emissions for European Union Nations over the period 1980-2012 and they conclude that there exists a negative relationship between $CO_2$ emissions and renewable energy consumption, and there exists a positive relationship between non-renewable energy consumption and $CO_2$ emissions. Bento and Moutinho (2016) find a negative relationship between renewable electricity consumption and $CO_2$ emissions in Italy. Dogan and Ozturk (2017) examine the relationship between renewable energy consumption, non-renewable energy consumption, real income and $CO_2$ emissions for the United States of America and they confirm the existence of a positive relationship between non-renewable energy consumption and $CO_2$ emissions and a negative relationship between renewable energy consumption and $CO_2$ emissions. Similar results are reached by Sinha, Shahbaz, and Balsalobre (2017) for N-11 countries.

### *2.3. Carbon dioxide emissions, renewable/non-renewable energy consumption and tourism development*

As we have discussed, the tourism sector depends on fossil fuel-based energy consumption to facilitate traveling and accommodation. Heavy reliance on this type of energy can contribute to $CO_2$ emissions, thus usage of renewable energy resources by the tourism sector can mitigate such emissions (Isik & Magdalena, 2017). The importance of tourism and its recognized impact on generating employment and income in various countries have stimulated work on analyzing its relationship with either non-renewable/renewable energy consumption or $CO_2$ emissions or both. However, the results are inconclusive. For instance, Liu, Lai, and Kuok (2012) find a bidirectional causal relationship between energy consumption and tourism development with regard to Taiwan. Similar results are reached by Tiwari, Ozturk, and Aruna (2013) for OECD countries; and Sekrafi and Sghaier (2018) in Tunisia.

Kuo, Liu, and Lai (2012) conclude that tourism receipts might increase energy consumption and $CO_2$ emissions in China. In contrast to this, Lee and Brahmasrene (2013) find that tourism may decrease $CO_2$ emissions for a panel of European Union countries, and similar results are found by Katircioglu (2014) with regard to Singapore. Zaman, Khan, and Ahmad (2011) find a unidirectional causal relationship stemming from tourism to $CO_2$ emissions. Similar results are found by Zhang and Gao (2016) in eastern China and Raza, Sharif, Wong, and

Abd Karim (2017) in the USA. Additionally, Katiricioglu (2014) confirms the contribution of tourism development to both energy consumption and $CO_2$ emissions in Turkey. Dwyer, Forsyth, Spurr, and Hoque (2010) find that tourism contributes to greenhouse gas emissions in Australia. Also, León, Arana, and Hernández-Alemán (2014) find that although tourism development contributes to environmental degradation in both developed and less developed countries, its effect is less in less developed countries. Similar results are found by Solarin (2014), Robaina-Alves, Moutinho, and Costa (2016), Sharif, Afshan, and Nisha (2017), Zaman, Shahbaz, Loganathan, and Raza (2016) and Dogan, Seker, and Bulbul (2017). Moreover, Ozturk (2016) referring to a panel of 34 developed and developing countries finds that there is a positive relationship between $CO_2$ emissions and tourism indicators and a negative relationship between energy consumption and tourism indicators. As for Paramati, Shahbaz, and Alam (2017), they find that tourism decreases environmental degradation in western European Union countries while it increases it in eastern European Union countries. Also, mixed results are found by Isik, Doğan, and Ongan (2017) for the causality relationship between energy consumption and tourist arrivals and receipts for the top-most visited countries.

As mentioned above, renewable energy consumption is now a vital determinant that can mitigate environmental degradation, but there are a limited number of studies that are concerned with the relationship between tourism development and renewable energy consumption. This stream of literature is yet to reach any clear conclusions. Among these studies, Ben-Jebli, Ben-Youssef, and Apergis (2014) find that tourist arrivals and renewable energy consumption mitigate $CO_2$ emissions for Central and South America and they confirm the bidirectional causal relationship between tourist arrivals and environmental degradation. Isik, Dogru, and Turk (2017) conclude that there is a unidirectional causal relationship from tourist arrivals to renewable energy consumption in Italy, Spain, Turkey and USA, and unidirectional causality from renewable energy consumption to tourist arrivals in China and no causality in France and Germany.

The above-mentioned studies use various methodologies including ARDL model, Johansen cointegration model, Generalized Method of Moments, panel cointegration, OLS, FMOLS, Pedroni and Kao panel co-integration techniques, wavelet transform framework, vector error correction model, etc. So far findings are mixed due to different methodologies used, variables used and time periods chosen. Moreover, the effect of renewable energy consumption on tourism development is not clear as there are very few studies that investigate this relationship.

## 3. Data and methodology

### *3.1. Model*

This study aims to assess the association between tourism, renewable and fossil fuel energy consumption, and $CO_2$ emissions in China following the frequency domain analysis. While analysing this association, we are interested in understanding the nature of co-movement among these variables, and not their long run coefficients. In doing so, we need to confirm their long run cointegrating association in the time domain, as the tests confirming this association are the diagnostic tests for assessing the co-movement among these variables. The question of including other variables might arise in this pursuit, and we need to explain the reason for not considering other variables. In keeping with the objective of this study, we need to assess the association of these variables through co-movement, and not through assessing long run coefficients. Hence, adding additional explanatory variables will not have any effect on the estimation results.

Therefore, this estimation processes have considered only four variables: tourism, renewable and fossil fuel energy consumption, and $CO_2$ emissions.

In keeping with the research objective, we hypothesize that there is a possible co-movement between tourism, renewable energy consumption, fossil fuel energy consumption, and $CO_2$ emissions for China in the frequency domain.

### *3.2. Data*

The main variables include tourist arrivals (TOR), renewable energy consumption (RENEW), energy consumption (ENC) and $CO_2$ emissions ($CO_2$) and all variables are in annual frequency ranging from 1974-2017. TOR is measured by the number of tourist arrivals per year in the country during the study period. Renewable energy consumption is measured in kilotons and energy consumption is calculated as the sum of total primary energy used. It is measured in kilogram oil equivalent. Finally, $CO_2$ as a proxy for environmental degradation is calculated as the total emission of carbon dioxide and is measured in kilotons. The data for all the variables except renewable energy, are obtained from the World Bank (World development indicator). Renewable energy data is collected from National Bureau of Statistics, China. It is converted into natural logarithm of difference series in order to acquire the return-series to make our conclusion more comparable. The time period is selected by the availability of data and to assure that data for all the variables under study is complete for the period 1974-2016. Aloui, Hkiri, Hammoudeh, and Shahbaz (2018) conducted a similar analysis with annual data from 1969-2014 for the oil price, inflation, exchange rate, and economic growth nexus in Saudi Arabia.

### *3.3. Methodology*

We employed different methods of wavelet in order to examine the linkage among tourism, energy consumption, renewable energy consumption and carbon dioxide emission. This is explained essentially by the ability of these methods to focus and follow the varying outlines of time scale. In fact, the technique of wavelet allows the prediction of time series' spectral features as being a time function and also an explanation of the variation over time of time series' periodic components. Particularly, we can use continuous wavelets, coherence of wavelet, multiple wavelet coherence and wavelet power between various approaches of wavelet technique. In addition, Ruan and Nunes (2009) argued that the technique of cross wavelets has the ability to decompose in the first time and reconstruct in the second time the following function:

$$x(t) = 1/C_{\psi} \int_{0}^{\infty}[\int_{-\infty}^{\infty} \mathrm{Wx}(u, s)\ \psi_{u,s}(t)\ du]\ ds/s^{2},\ s>0 \quad (1)$$

The efficiency of the approach of wavelet coherence is due to its measure of the coefficient across series of localized correlation especially in the domain of time-frequency. By the way, the wavelet method coherence is measured through dividing the smoothed CWS' absolute value by the WPS of smoothed individual product for each series.

$$R^2(u, s) = \frac{|S(s-1Wxy(u,s))|\verb|^|2}{(S(s-1Wx(u,s)|\verb|^|2)\ S(s-1Wy(u,s)\verb|^|2)} \quad (2)$$

After employing both techniques such as wavelet coherence and cross-wavelet, we may apply for the methods of multiple and partial wavelet. Particularly, these two methods contribute in the inclusion of control variables in a multivariate framework. However, this is not possible via both coherency approaches of wavelet and wavelet coherence. We can thus detect the impact of control variables on carbon dioxide emission. Moreover, in the framework of a bivariate wavelet and in order to avoid series 'comparison, we use the methods of partial and multiple wavelet coherency. Some authors suggested that these methods eliminate the bias of oscillations' low frequency, which exists frequently in the prediction of power spectrum of wavelet approach (Liu, Liang, & Weisberg, 2007; Veleda, Montagne, & Araujo, 2012). We should note that the techniques of a multivariate wavelet add a new variable which is considered a third variable and also a conditioning factor.

Besides, the difference between partial and multiple wavelet coherence methods is that the partial investigates the two variables' influences on a third one, but the second wavelet method is considered more akin to a various association, which is thus applied for testing the impact of many independent variables on a single one.

The following expression presents the approach of the specific method of partial wavelet coherence. It allows the identification of the wavelet coherence (WC) among both series ($y, x_1$) after deleting the third series ($x_2$) impacts. The expression of the current function is showed as follows:

$$RP^2 (y, x_1x_2) = \frac{|R(y,x1)-R(y,x2).R(y,x1)|*\hat{}2}{[1-R(y,x2)]\hat{}2[1-R(x2,x1)]\hat{}2} \quad (3)$$

By using PWC technique, we may employ multiple wavelet coherency approach. The latter is identical to the multiple associations. In fact, in order to predict the coherence of many variables on a dependent one variable, we use the MWC, which has the power to examine this linkage. The model function of multivariate wavelet coherence is presented as follows:

$$RM^2 (y, x_2x_1) = \frac{R2(y,x1)+ R2(y,x2)-2Re[R.(y,x1).R(y,x2)*.\ R(x1,x2)*}{1-R2(x1,x2)} \quad (4)$$

## 4. Empirical results

This section discusses the data analysis focusing on the dynamic relationship between tourism, energy consumption, renewable energy consumption and $CO_2$ emissions evidence from China.

### *4.1. Unit Root test and Long-run Cointegration*

The main objective of this study is to investigate the relationship between tourism, renewable energy consumption, energy consumption and $CO_2$ emission in China. Before applying the statistical analysis, the time series of our variables are transformed into natural logarithms. The reason behind the transformation of natural series into logarithms is because we are assuming the information that results are more efficient in returns rather than actual value (Tiwari, Bhanja, Dar, & Islam, 2015). Fig. 1, plots the actual as well as log-transformed difference time series data for all the variables under study. It can be observed that the actual series appears to be non-stationary, whereas converted first difference of all the series seems to be stationary. Moreover, all the actual series demonstrates rising trends.

***<Insert Figure 1 here>***

Conversely, substantial fluctuations can be seen in the real difference series indicating that there exist significant changes in all the variables under the study and for the entire study period. The descriptive statistics and correlation matrix for the variables are shown in Table 1. The $CO_2$ emission and renewable energy consumption show the highest and the lowest standard deviation, respectively. All the series have accepted the Jarque-Bera test and confirm that they are not normally distributed, which is common for most of the time series data (Shahzad, et al., 2017). Furthermore, the correlation matrix shows significant relationships between the variables.

***<Insert Table 1 here>***

Next, the autoregressive distributed lag method for cointegration is used to estimate the long run relationship between tourism, renewable energy consumption, energy consumption and $CO_2$ emission. Table 3 shows the results of ARDL cointegration method.

***<Insert Table 2 here>***

The ARDL results reject the null hypothesis of no cointegration against the alternative hypothesis that a valid long-run relationship exists between tourism, renewable energy consumption, and $CO_2$ emission in China as the value of the $F$-statistics is greater than the upper bound critical value at 1 percent level of significance.

***<Insert Table 3 here>***

The Johansen and Juselius (1990) cointegration method is used to estimate the long run relationship. Table 4 represents the calculated and critical values of Trace statistics and Maximum Eigenvalue statistics of the Johansen and Juselius (1990) cointegration method. The results indicate the rejection of the null hypothesis of no cointegration in the model at a significance level of 5 percent in favor of the alternative hypothesis that there exists one or more cointegrating vectors. The findings confirm the existence of long-run relationship between tourism, renewable energy consumption, energy consumption and $CO_2$ emission in China.

### *4.2. Continuous Wavelet Transform*

Continuous wavelet power spectrum results for TOR, RENEW, ENC and $CO_2$ emission for China are displayed in Fig. 2. The horizontal axis measures the time period depicting five-years in progression from 1974-2016. The Y-axis measures the periodic cycle say 0-4, 4-8 etc. The direction of Y-axis is in reverse scale, i.e., closer to the Y-axis represents more long term scale. It can be seen that in the case of TOR, there are patterns of strong variance in small-medium runs. As for RENEW and ENC, the high variance is visible in small scales, but not in medium and long runs, while $CO_2$ emission has a strong variance in the long run (lower panel, right, Fig. 2). TOR mostly exists in small time scales during 1981-1985 and also for medium scales in between 1985-1990. However, for the entire study period, high-scale variance seems to be almost non-existent. Alternatively, inbound tourism is a bit volatile in the short-medium run, but the stability remains in the long-run. In the cases of RENEW and ENC, a strong variance exists in periods 0-4 yearly cycles during 2010-2015. As for $CO_2$ emission, a strong variance can be seen in the long-run during 1985-2005. These outcomes suggest that TOR, RENEW, ENC show more variance in the medium-run, but $CO_2$ emission has a significant variance in the medium-long run. Also, the common islands between the two series exist during 1980-1985 for TOR and $CO_2$ emission and later 2010-2015 for RENEW and ENC (Fig. 2). The relationship between the described patterns in the bivariate relationship using continuous wavelet transform (Fig. 2) is not very clear and comprehensible. Moreover, the connections between the patterns are low, hence, further investigation is performed using wavelet coherence.

***<Insert Figure 2 here>***

### *4.3. Wavelet Coherence*

The results of the bivariate relationship between the variables using wavelet coherence are presented in Fig. 3. The wavelet transform coherence locates the sections in time-frequency space in which two time series co-vary. Fig. 3 provides some interesting findings. The results of wavelet coherence for TOR-RENEW shows that in the period of 0-4 years cycle during 2012 onwards, the arrows are right-side-up explaining that the variables are in-phase showing cyclic effect with RENEW as leading variable suggesting that renewable energy consumption can predict the number of international tourists flowing into the country. Renewable energy consumption (RENEW) is the leading variable is this co-movement, and thereby, it can act as a movement predictor for the TOR, which is the tourist arrivals. The result for TOR with ENC and $CO_2$ (upper panel) emission is quite similar, revealing that in the period of 4-8 years cycle during 1985-1990, the arrows are left-side-up suggesting that the variables are out-phase and indicating an anti-cyclic effect with ENC and $CO_2$ lagging. It indicates that ENC and $CO_2$ emission tend to have delayed reactions to a change in international tourist flows. The RENEW-ENC results are that in the period of 0-4 cycle during 2000-2007, the arrows are left-side-up indicating that ENC-RENEW is out-phase showing anti-cyclic effect with ENC lagging. Moreover, the results of RENEW-$CO_2$ emission suggest that in the period of 0-4 year cycle during 2009-2013, the arrows are left-side-down explaining that the variables are out-phase and showing anti-cyclic effect with $CO_2$ is lagging. Alternatively, the level of $CO_2$ emission depends on the changes in the renewable energy consumption. Finally, the result of ENC-$CO_2$ emission shows that 4-16 years cycle during 1985-2015, the arrows are mostly right-side-up explaining that ENC-$CO_2$ emission is in-phase displaying a cyclic effect with $CO_2$ emission leading, which indicates that fossil fuel energy consumption can predict the future changes in the level of $CO_2$ emission. Overall, the results of wavelet coherence reveal that tourism is influenced by renewable energy consumption. Moreover, renewable energy consumption can lower carbon emission and increase international tourist flows in the short-medium run for sustainable development in China. Conversely, tourism can influence ENC and $CO_2$ in China.

***<Insert Figure 3 here>***

### *4.4. Partial Wavelet Coherence*

This subsection presents the results of partial and multiple wavelet coherence where, PWC is the partial wavelet coherence result (left-panel, Fig. 4), and MWC explains the multiple wavelet coherence plots (right-panel) between tourism, energy consumption, renewable energy consumption and $CO_2$ emission in China. Fig. 4a reports the partial wavelet coherence between energy consumption and renewable energy consumption after canceling out the $CO_2$ emission. The correlation is found to be weak and only one red color significant island is identified during 2011-2013, for 4-8 years cycle (medium-run horizon). However, when considering $CO_2$ emission in the ENC-RENEW relationship (Fig. 4b), a comparatively different condition is observed. A strong co-movement is noticed for both medium and high-frequency bands during the entire sample period. Predominantly, in the short-run, one island from 0-4 years cycle, where the correlation ranges from 0.9-1.0 (strong correlation) is noticed. In the medium-long run, the presence of one island in whole 4-8- and 8-16-year cycles is identified, with the correlation ranging from 0.8-1.0. Overall, the partial and multiple wavelet coherence specify a robust effect of $CO_2$ emission in examining the relationship between RENEW and ENC in China. The results are also consistent with the pair-wise Granger causality test, verifying the existence of causality running from ENC to RENEW and from RENEW to $CO_2$ emission.

***<Insert Figure 4 here>***

Fig. 4c shows the partial wavelet coherence between energy consumption and renewable energy after canceling out the tourism effect. The correlation is found to be weak and only one yellow color significant island is identified in the 0-4 years cycle (short-run horizon) during 2002-2004. But, when considering tourism in the relationship between ENC and RENEW (Fig. 4d), a strong co-movement in short-medium period is noticed. In the 0-4 year cycle, we found the presence of three islands during 1987-1991, 1997-2005 and 2011-2013 time period, where the correlation ranges between 0.7- 0.9. However, in the medium-run, there is a strong co-movement between ENC, RENEW and TOR. In the 4-8 year cycle, one strong red island is found during 1982-1986 with the correlation ranging from 0.7-0.8. The results are also consistent with the pair-wise Granger causality test, signifying the existence of causality running from ENC to RENEW and from RENEW to TOR in China. The results are consistent with the results of wavelet coherence that renewable energy influences inbound tourism in the short-medium run, but there is no effect in the long-run.

Figs. 4e and 4g illustrate the partial wavelet coherence between RENEW and $CO_2$ emission canceling out ENC and TOR, respectively. The correlation is found to be weak and only one small red color significant island is identified in a 0-4 years cycle during 2008-2010 (cancelling out ENC) and 2006-2009 (cancelling out TOR). However, when considering ENC and TOR, in the relationship between RENEW and $CO_2$ emission (Figs. 4f and 4h), a strong co-movement is observed in the short-medium run of RENEW, $CO_2$ emission and ENC. In the 0-4- and 4-8-year cycles, we found the existence of two red islands during 1989-1991 and 2003-2011, where the value of correlation ranges between 0.7-0.9. In Fig. 4h, from the 0-4- and 4-8-year cycles, we found the presence of three red islands during 1986-1991 and 2006-2012 in the short-run and from 1981-1986 in the medium-run, where the value of correlation ranges between 0.7-0.9. The results confirm the earlier findings (wavelet coherence) that tourism affects renewable energy consumption and carbon emissions in the short and medium run. The emergence of electric vehicles and vehicles run by clean energy sources are being implemented by the policymakers in various tourism destinations in China, and this move might increase the demand for renewable energy and decrease the level of $CO_2$ emissions in the short run. This segment of the results might not hold true for the long run, as the gradual rise in tourist arrivals in these destinations might gradually increase the level of $CO_2$ emissions through rise in the tourism-allied industrial activities and tourism related activities. In order to enhance the attractiveness of these destinations, these tourism-allied industrial sectors will be boosted through fossil fuel energy consumption. In such a scenario, long run association can be established through the intervention of tourism investment in pursuit of augmenting renewable energy consumption.

Figs. 4i and 4k show the partial wavelet coherence between TOR and $CO_2$ emission canceling out ENC and RENEW, respectively. The correlation is found to be weak and only one small red color significant island is identified for the 4-8-year cycle during 1981-1987 (cancelling out RENEW), whereas no relationship is found between TOR and $CO_2$ emission (cancelling ENC). The results suggest that tourism and $CO_2$ emission are correlated. However, when considering ENC and RENEW, in the relationship between TOR and $CO_2$ emission (Fig.

4j and 4l), a solid co-movement in the short-medium run is detected for RENEW, $CO_2$ emission, and TOR. In the 0-4- and 4-8-year cycle, we found the existence of three red islands during 1987-1993 and 1997- 2001 in the short-horizon and during 1980-1986 in the medium-horizon, where the value of correlation ranges between 0.7-0.8. In Fig. 4l, from the 0-4- and 4-8-year cycle, we found the presence of two red islands during 1988-1990 in the short-run and from 1981-1989 in the medium-run, where the value of correlation ranges between 0.7-0.8. It is evident that energy consumption and renewable energy consumption influence the correlation between TOR and $CO_2$ emission.

Figs. 4m and 4o display the PWC between ENC and $CO_2$ emission canceling out TOR and RENEW, respectively. The correlation is found to be very strong and a one large red color significant island is identified for 4-8- and 8-16-year cycle during the whole period (cancelling out RENEW and TOR individually) illustrating the general concerns that ENC and $CO_2$ emission are highly correlated. While considering TOR and RENEW, in the relationship between ENC and $CO_2$ emission (Fig. 4n and 4p), we identified a firm co-movement in short-medium-long run of RENEW, $CO_2$ emission, and TOR. In the 0-4 year cycle, we found the existence of one red island during 1986-1991 and in the 4-8 and 8-16 year cycle, we find one large red island for an entire period where the value of correlation ranges between 0.8 to 0.9. In Fig. 4p, from the 0-4 year cycle, we found the presence of two red islands during 1988-1991 and 1996-2001 in the short-run. In the 4-8 and 8-16 period, again we see one large red island for an entire period where the value of correlation ranges from 0.8-0.9. In other words, tourism and renewable energy consumption do affect the correlation between energy consumption and $CO_2$ emission.

Figs. 4q and 4s explain the partial wavelet coherence between the sets: changes in TOR and ENC excluding RENEW and $CO_2$ emission. The strong co-movement is located at the 4-8-

year cycle during 1981-1985 in a medium-run (cancelling out RENEW), whereas, a weak co-movement is presented in the 0-4 year cycle during 1998-1999 (cancelling out $CO_2$ emission). There is not much correlation between TOR and ENC, if RENEW and $CO_2$ are excluded. When focusing on TOR and ENC in the relationship between RENEW and $CO_2$ emission (Figs. 4r and 4t), we identify a strong co-movement in the short-medium year cycle where the value of the correlation ranges from 0.8-0.9 suggesting that RENEW and $CO_2$ influence the relationship between TOR and ENC. Fig (4u) and (4w) display the PWC between TOR and RENEW canceling out $CO_2$ emission and ENC, respectively. The correlation is found to be very strong and only one small red color significant island is identified during 1982-1987 (cancelling out $CO_2$ emission and ENC individually) for the 4-8-year cycle (long run). The results confirm that TOR and RENEW are correlated in the medium-run with the influences of $CO_2$ and ENC. While considering $CO_2$ emission and ENC, in the relationship between RENEW and TOR (Fig. 4v and 4x), we identify a firm co-movement in short-medium run of RENEW, $CO_2$ emission, and TOR. In the 0-4-year cycle, we found the existence of one red island during 1986-1991 and in the 4-8 year cycle, one large red island for 1981-1989 period is seen where the value of correlation ranges from 0.8-0.9. In Fig. 4x, from the 0-4-year cycle, we found the presence of two red islands during 1986-1992 and 2011-2012 in the short-run. In 4-8 cycle, again one large red island for 1980-1988 period is seen, where the value of correlation ranges from 0.8-0.9. So, $CO_2$ and ENC affect the TOR-RENEW relationship. Overall, the findings confirm that tourism is correlated with renewable energy and $CO_2$ emission especially in the short-medium run, but the correlation disappears in the long-run. However, $CO_2$ emission affects fossil fuel energy as well as renewable energy consumption in the long-run. As China is gradually moving towards the business of ecotourism, therefore it is important for the policymakers to retain and improve the environmental quality of the tourism destinations. Henceforth, the policymakers might try to implement renewable energy solutions by gradually replacing the fossil fuel energy solutions, as the latter is responsible for rise in $CO_2$ emissions in the ambient atmosphere. So, the rise in the $CO_2$ emissions compelled the policymakers to increase renewable energy consumption and reduce fossil fuel energy consumption.

**5. Conclusion**

By far, we have evaluated the associative co-movement between tourism, renewable and fossil fuel energy consumption, and $CO_2$ emission in China, by means of wavelet transform and wavelet coherence methods. The contribution of this study is in terms of divulging the way, in which the associative movement between sustainable tourism and ecological sustainability in China changes its course along the frequency domains. For temporal domain, our results demonstrate heterogeneous association among the model parameters, whereas in frequency domain, the associations are both coherent and the model parameters are having lead-lag associations. The phase-wise outcomes show that these associative movements vary along the temporal domain for medium and short runs. Lastly, the results confirm the presence of significant association between the model parameters in the frequency domain through their lead-lag associations.

Also, the findings suggest that energy consumption and $CO_2$ emission act as lagging indicators for tourism. In other words, international tourism increases the energy consumption and $CO_2$ emissions. Given that China has experienced an estimated 288% increase in international tourist numbers over the 15-year period from 1995-2009 (Gössling et al., 2013), it is highly plausible that this tourism growth has not been environmentally sustainable. International tourism involves such a movement of people over long distances, as well as their accommodation and activities, the direct contribution to greenhouse gases is clearly going to be quite substantial.

So, the question arises: can China's tourist growth continue while, in overall terms, the emissions of $CO_2$ associated with China decline? Here, our results are supportive of this outcome being possible. That is, our findings suggest that tourism and consumption of renewable energy facilitate reduced $CO_2$ emissions in the short-medium run in China. Renewable energy acts as a leading indicator implying that converting energy consumption to renewable energy further enhances the international tourist flows and promotes sustainable tourism by lowering $CO_2$ emission. This suggests that policy makers should make contingency plans for generating renewable energy to deal with the threat of global warming in the next two-to-three years and to promote tourism with an emphasis on sustainability.

As mentioned earlier, energy consumption in tourism, to a large extent, comes from transportation activities involving long distance air and sea travelling, hence, promoting a sectoral shift from long distance international tourism to domestic and regional tourism can moderate $CO_2$ emission and hence global warming. Moreover, construction of accommodation including multi-storied buildings is an energy intensive activity (Rossello-Batle, Moia, Cladera, & Martinez (2010) point out the importance of recycling construction materials to counteract global warming). The adoption of clean technologies using renewable energy for production purposes and promoting eco-tourism for its sustainability has the potential to achieve the objectives of developing the tourist industry and reducing $CO_2$ emission.

## References


Aguiar-Conraria, L., Azevedo, N., & Soares, M. J. (2008). Using wavelets to decompose the time frequency effects of monetary policy. *Physica A: Statistical Mechanics and its Applications*, *387*(12), 2863-78.

Aguiar-Conraria, L., & Soares, M. J. (2011). Oil and the macroeconomy: using wavelets to analyze old issues. *Empirical Economics*, *40*(3), 645-55.

Alam, M. J., Begum, I. A., Buysse, J., Rahman, S., & Huylenbroeck, G. Y. (2011). Dynamic modelling of the causal relationship between energy consumption, $CO_2$ emissions and economic growth in India. *Renewable and Sustainable Energy Reviews*, *15*(6), 3243-51.

Al-Mulali, U., Fereidouni, H. G., & Mohammed, A. H. (2015). The effect of tourism arrival on $CO_2$ emissions from the transportation sector. *International Journal of Tourism and Hospitality Research*, *26*(2), 230-43.

Aloui, C., Hkiri, B., Hammoudeh, S., & Shahbaz, M. (2018). A Multiple and Partial Wavelet Analysis of the Oil Price, Inflation, Exchange Rate, and Economic Growth Nexus in Saudi Arabia. *Emerging Markets Finance and Trade*, *54*(4), 935-56.

Alshehry, A. S., & Belloumi, M. (2015). Energy consumption, carbon dioxide emissions and economic growth: the case of Saudi Arabia. *Renewable and Sustainable Energy Reviews*, *41*, 237-47.

Álvarez-Herranz, A., Balsalobre-Lorente, D., Cantos, J. M., & Shahbaz, M. (2017). Energy Innovations-GHG Emissions Nexus: Fresh Empirical Evidence from OECD Countries. *Energy Policy*, *101*, 90-100.

Apergis, N., & Payne, J. E. (2009). $CO_2$ emissions, energy usage, and output in Central America. *Energy Policy*, *37*(8), 3282–86.

Apergis, N., & Payne, J. E. (2010). Renewable energy consumption and growth in Eurasia. *Energy Economics*, *32*(6), 1392-97.

Aslanidis, N., & Iranzo, S. (2009). Environment and development: is there a Kuznets curve for $CO_2$ emissions? *Applied Economics,* 41(6), 803-10.

Beijing Municipal Bureau of Statistics (2014). Beijing Statistical Yearbook 2014. Available at: http://tjj.beijing.gov.cn/nj/main/2014_tjnj/index.htm

Ben-Jebli, M., & Ben-Youssef, S. (2015). "The environmental Kuznets curve, economic growth, renewable and non-renewable energy, and trade in Tunisia." *Renewable and Sustainable Energy Reviews, 47*, 173-85.

Ben-Jebli, M., Ben-Youssef, S., & Apergis, N. (2014). The dynamic linkage between $CO_2$ emissions, economic growth, renewable energy consumption, number of tourist arrivals and trade. MPRA Paper, No. 57261.

Bento, J. P. C., & Moutinho, V. (2016). $CO_2$ emissions, non-renewable and renewable electricity production, economic growth and international trade in Italy. *Renewable and Sustainable Energy Reviews*, *55*, 142-55.

Bilgili, F., Koçak, E., & Bulut, Ü. (2016). The dynamic impact of renewable energy consumption on $CO_2$ emissions: A revisited Environmental Kuznets Curve approach. *Renewable and Sustainable Energy Reviews*, *54*, 838-45.

Chen, L., Thapa, B., & Yan, W. (2018). The relationship between tourism, carbon dioxide emissions, and economic growth in the Yangtze River Delta, China. *Sustainability*, *10*(7), 2118.

Chiu, C. L. & Chang, T. C. (2009). What proportion of renewable energy supplies is needed to initially mitigate $CO_2$ emissions in OECD member countries? *Renewable and Sustainable Energy Reviews*, *13*(6), 1669-74.

Dicky, D. A., & Fuller, W. A. (1979). Distribution of the Estimators for Autoregressive Time Series with a Unit Root. *Journal of the American Statistical Association*, *74*, 427-31.

Dogan, E., Seker, F., & Bulbul, S. (2017). Investigating the impacts of energy consumption, real GDP, tourism and trade on $CO_2$ emissions by accounting for cross-sectional dependence: A panel study of OECD countries. *Current Issues in Tourism*, *20*(16), 1701-19.

Dogan, E., & Ozturk, I. (2017). The influence of renewable and non-renewable energy consumption and real income on $CO_2$ emissions in the USA: Evidence from structural break tests. *Environmental Science and Pollution Research*, *24*(11), 10846-54.

Dogan, E., & Seker, F. (2016). The influence of real output, renewable and non-renewable energy, trade and financial development on carbon emissions in the top renewable energy countries. *Renewable and Sustainable Energy Reviews*, *60*, 1074-85.

Dwyer, L., Forsyth, P., Spurr, R., & Hoque, S. (2010). Estimating the carbon footprint of Australian tourism. *Journal of Sustainable Tourism*, *18*(3), 355-76.

EIA. (2017). International Energy Outlook. *U.S. Energy Information Administration Website*, September 14. https://www.eia.gov/outlooks/ieo/pdf/0484(2017).pdf (accessed July 6, 2019).

Gössling, S., Scott, D., & Hall, C. M. (2013). Challenges of tourism in a low-carbon economy. *Wiley interdisciplinary reviews: Climate change*, *4*(6), 525-38.

Grinsted, A., Moore, J. C., & Jevrejeva, S. (2004). Application of the cross wavelet transform and wavelet coherence to geophysical time series. *Nonlinear processes in geophysics*, *11*(5/6), 561-66.

Ibrahiem, D. M. (2016). Environmental Kuznets curve: An empirical analysis for carbon dioxide emissions in Egypt. *International Journal of Green Economics*, *10*(2), 136-50.

Isik, C., & Magdalena, R. (2017). Investigation of the Relationship between Renewable Energy, Tourism Receipts and Economic Growth in Europe. *Statıstıka-Statıstıcs And Economy Journal*, *97*(2), 85-94.

Isik, C., Doğan, E., & Ongan, S. (2017). Analyzing the Tourism–Energy–Growth Nexus for the Top 10 Most-Visited Countries. *Economies*, *5*(4), 1-13.

Isik, C., Dogru, T., & Turk, E. S. (2017). Nexus of linear and non-linear relationships between tourism demand, renewable energy consumption, and economic growth: Theory and evidence. *International Journal of Tourism Research*, *20*(1), 38-49.

Jalil, A. & Mahmud, S. F. (2009). Environmental Kuznets curve for $CO_2$ emissions: A cointegration analysis for China. *Energy Policy, 37*(12), 5167-72.

Jayanthakumaran, K., Verma, R., & Liu, Y. (2012). $CO_2$ emissions, energy consumption, trade, and income: a comparative analysis of China and India. *Energy Policy*, *42*, 450-60.

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.

Katircioglu, S. T. (2014). Testing the tourism-induced EKC hypothesis: The case of Singapore. *Economic Modelling*, *41*, 383-91.

Kristoufek, L. (2015). What are the main drivers of the Bitcoin price? Evidence from wavelet coherence analysis. *PloS ONE*, *10*(4), 1-15.

Kuo, K.C., Liu, M., & Lai, S. L. (2012). Effect of tourism development on energy consumption, $CO_2$ and economic growth in China. *Advanced Materials Research*, *524-527*, 3380-83.

Lean, H. H., & Smyth, R. (2010). $CO_2$ emissions, electricity consumption and output in ASEAN. *Applied Energy*, *87*(6), 1858-64.

Lee, J. W., & Brahmasrene, T. (2013). Investigating the influence of tourism on economic growth and carbon emissions: Evidence from panel analysis of the European Union. *Tourism Management*, *38*, 69-76.

Lenzen, M., Sun, Y. Y., Faturay, F., Ting, Y. P., Geschke, A., & Malik, A. (2018). The carbon footprint of global tourism. *Nature Climate Change*, *8*(6), 522-528.

León, C. J., Arana, J. E., & Hernández Alemán, A. (2014). $CO_2$ emissions and tourism in developed and less developed countries. *Applied Economics Letters*, *21*, 1169-73.

Li, L., Li, J., Tang, L., & Wang, S. (2019). Balancing Tourism's Economic Benefit and $CO_2$ Emissions: An Insight from Input–Output and Tourism Satellite Account Analysis. *Sustainability*, *11*(4), 1052.

Lin, B., & Moubarak, M. (2014). Renewable energy consumption – Economic growth nexus for China. *Renewable and Sustainable Energy Reviews*, *40*, 111-17.

Liu, M., Lai, S. L., & Kuok, C. (2012). Economic growth, energy consumption and tourism development in Taiwan: A Granger causality approach. *Advanced Materials Research*, *524-527*, 3376-9.

Mihanović, H., Orlić, M., & Pasarić, Z. (2009). Diurnal thermocline oscillations are driven by tidal flow around an island in the Middle Adriatic. *Journal of Marine Systems*, *78*, S157-68.

Ng, E. K., & Chan, J. C. (2012). Geophysical applications of partial wavelet coherence and multiple wavelet coherence. *Journal of Atmospheric and Oceanic Technology*, *29*(12), 1845-53.

Niu, S., Ding, Y., Niu, Y., Li, Y., & Luo, G. (2011). Economic growth, energy conservation and emissions reduction: A comparative analysis based on panel data for 8 Asian-Pacific countries. *Energy Policy*, *39*(4), 2121-31.

Ocal, O., & Aslan, A. (2013). Renewable energy consumption – economic growth nexus in Turkey. *Renewable and Sustainable Energy Reviews*, *28*, 494-99.

Othman, N., Mohamed, S., & Aziz, F. (2012). Tourism activities and its impact on environmental sustainability in coastal areas. Paper presented at the 2nd international conference on Economics, Trade and Development, Singapore.

Ozturk, I. (2010). A literature survey on energy–growth nexus. *Energy policy*, *38*(1), 340-49.

Ozturk, I. (2016). The relationships among tourism development, energy demand, and growth factors in developed and developing countries. *International Journal of Sustainable Development & World Ecology*, *23*(2), 122-31.

Paramati, S. R., Shahbaz, M., & Alam, Md. S. (2017). Does tourism degrade environmental quality? A comparative study of Eastern and Western European Union. *Transportation Research Part D: Transport and Environment*, *50*, 1-13.

Phillips, P. B., & Perron, P. (1988). "Testing for a Unit Root in Time Series Regression." *Biometrika*, *75*(2), 335-46.

Raza, S. A., Sharif, A., Wong, W. K., & Abd Karim, M. Z. (2017). Tourism development and environmental degradation in the United States: evidence from the wavelet-based analysis. *Current Issues in Tourism*, *20*(16), 1768-90.

Riti, J. S., Song, D., Shu, Y., & Kamah, M. (2017). Decoupling $CO_2$ emission and economic growth in China: Is their consistency in estimation results in analyzing environmental Kuznets curve? *Journal of Cleaner Production*, *168*, 1217-29.

Robaina-Alves, M., Moutinho, V., & Costa, R. (2016). Change in energy-related $CO_2$ (carbon dioxide) emissions in Portuguese tourism: A decomposition analysis from 2000 to 2008. *Journal of Cleaner Production*, *111*, 520-28.

Rossello-Batle, B., Moia, A., Cladera, A., and Martinez, V. (2010). Energy use, $CO_2$ emissions and waste throughout the life cycle of a sample of hotels in the Balearic Islands. *Energy and Buildings*, *42*(4), 547-58.

Say, N. P., & Yucel, M. (2006). Energy consumption and CO2 emissions in Turkey: empirical analysis and future projection based on an economic growth. *Energy Policy*, *34*(18), 3870-76.

Sebri, M., & Ben-Salha, O. (2014). On the causal dynamics between economic growth, renewable energy consumption, $CO_2$ emissions, and trade openness: Fresh evidence from BRICS countries. *Renewable and Sustainable Energy Reviews*, *39*, 14-23.

Sekrafi, H., & Sghaier, A. (2018). Exploring the relationship between tourism development, energy consumption, and carbon emissions: A case study of Tunisia. *International Journal of Social Ecology and Sustainable Development*, *9*(1), 26-39.

Shahbaz, M., Farhani, S., & Ozturk, I. (2015). Do coal consumption and industrial development increase environmental degradation in China and India? *Environmental Science and Pollution Research*, *22*(5), 3895-907.

Shahbaz, M., Khraief, N., Uddin, G. S., & Ozturk, I. (2014). Environmental Kuznets curve in an open economy: Bounds testing and causality analysis for Tunisia. *Renewable, and Sustainable Energy Reviews*, *34*, 325-36.

Shahbaz, M., & Sinha, A. (2019). Environmental Kuznets curve for $CO_2$ emissions: a literature survey. Journal of Economic Studies, 46(1), 106-168.

Shahzad, S. J. H., Kumar, R. R., Zakaria, M., & Hurr, M. (2017). Carbon emission, energy consumption, trade openness and financial development in Pakistan: A revisit. *Renewable and Sustainable Energy Reviews*, *70*, 185-92.

Sharif, A., Afshan, S., & Nisha, N. (2017). Impact of tourism on $CO_2$ emission: Evidence from Pakistan. *Asia Pacific Journal of Tourism Research*, *22*(4), 408-21.

Shuxin, W., Genxu, W., & Yiping, F. (2016). Factors influencing the energy efficiency of tourism transport in China. *Journal of Resources and Ecology*, *7*(4), 246-254.

Sinha, A., Shahbaz, M., & Balsalobre, D. (2017). Exploring the relationship between energy usage segregation and environmental degradation in N-11 countries." *Journal of Cleaner Production*, *168*, 1217-29.

Solarin, S. A. (2014). Tourist arrivals and macroeconomic determinants of $CO_2$ emissions in Malaysia. *International Journal of Tourism and Hospitality Research*, *25*(2), 228–241.

Tang, C. F., & Tan, B. W. (2015). The impact of energy consumption, income and foreign direct investment on carbon dioxide emissions in Vietnam. *Energy*, *79*, 447-54.

Tang, M., & Ge, S. (2018). Accounting for carbon emissions associated with tourism-related consumption. *Tourism Economics*, *24*(5), 510-525.

Tang, Z., Shang, J., Shi, C., Liu, Z., & Bi, K. (2014). Decoupling indicators of $CO_2$ emissions from the tourism industry in China: 1990–2012. *Ecological Indicators*, *46*, 390-397.

Tiwari, A. K., Bhanja, N., Dar, A. B., & Islam, F. (2015). Time-frequency relationship between share prices and exchange rates in India: Evidence from continuous wavelets. *Empirical Economics*, *48*(2), 699-714.

Tiwari, A. K., Ozturk, I., & Aruna, M. (2013). Tourism, energy consumption and climate change in OECD countries. *International Journal of Energy Economics and Policy*, *3*(3), 247-61.

Torrence, C., & Compo, G. P. (1998). A practical guide to wavelet analysis. *Bulletin of the American Meteorological Society*, *79*(1), 61-78.

Torrence, C., & Webster, P. J. (1999). "Interdecadal changes in the ENSO–monsoon system". *Journal of Climate*, *12*(8), 2679-90.

UNEP (2008). *Climate Change and Tourism: Responding to Global Challenges*. World Tourism Organization, Madrid, Spain.

UNWTO. (2017). Tourism Highlights. *UNWTO Website*. https://www.e-unwto.org/doi/pdf/10.18111/9789284419029 (accessed July 6, 2019).

UNWTO (2018). *UNWTO-WTCF City Tourism Performance Research: Beijing Case Study*. Working Paper.

WTTC. (2018). Travel and Tourism Economic Impact 2018 China. *WTTC Website*. https://www.wttc.org/-/media/files/reports/economic-impact-research/countries-2018/china2018.pdf (accessed December 12, 2018).

Wu, P., & Shi, P. (2011). "An estimation of energy consumption and $CO_2$ emissions in tourism sector of China." *Journal of Geographical Sciences*, *21*(4), 733-45.

Zaman, K., Khan, M. M., & Ahmad, M. (2011). Exploring the relationship between tourism development indicators and carbon emissions: A case study of Pakistan. *World Applied Sciences Journal, 15*(5), 690-701.

Zaman, K., Shahbaz, M., Loganathan, N., & Raza, S. A. (2016). Tourism development, energy consumption and environmental Kuznets curve: Trivariate analysis in the panel of developed and developing countries. *Tourism Management*, *54*, 275-83.

Zeshan, M., & Ahmed, V. (2013). Energy, environment and growth nexus in South Asia. *Environment Development, and Sustainability*, *15*(6), 1465-75.

Zhang, L., & Gao, J. (2016). Exploring the effects of international tourism on China's economic growth, energy consumption, and environmental pollution: Evidence from a regional panel analysis. *Renewable and Sustainable Energy Reviews*, *53*, 225-34.

Zoundi, Z. (2017). $CO_2$ emissions, renewable energy and the environmental Kuznets curve, a panel cointegration approach. *Renewable and Sustainable Energy Reviews*, *72*, 1067-75.

**Table 1.** Descriptive statistics

| | TOR | RENEW | ENC | CO2 |
|---|---|---|---|---|
| Mean | 6759.656 | 211489.900 | 1112.545 | 4530932.000 |
| Maximum | 15053.940 | 306458.300 | 2236.730 | 10291927.000 |
| Minimum | 168.234 | 174584.900 | 537.175 | 1196194.000 |
| Std. Dev. | 5129.251 | 24102.240 | 555.444 | 3158145.000 |
| Skewness | 0.184 | 0.722 | 0.842 | 0.826 |
| Kurtosis | 1.451 | 1.828 | 2.154 | 2.159 |
| Jarque-Bera | 24.436 | 61.562 | 6.214 | 6.008 |
| Probability | 0.000 | 0.000 | 0.045 | 0.050 |
| Correlation Matrix | | | | |
| TOR | 1 | | | |
| RENEW | 0.619*<br>(0.000) | 1 | | |
| ENC | 0.926*<br>(0.000) | -0.555*<br>(0.000) | 1 | |
| CO2 | 0.931*<br>(0.000) | -0.632*<br>(0.000) | 0.992*<br>(0.000) | 1 |

Note: * denotes the rejection of the null hypothesis at the 1% significance level

**Table 2: Lag Length Selection & Bound Testing for Cointegration**

| Lags Order | AIC | HQ | SBC | F-test Statistics |
|---|---|---|---|---|
| 0 | -3.258 | -3.796 | -3.689 | |
| 1 | -12.209 | -12.304 | -12.165 | 59.456* |
| 2 | -12.05 | -11.998 | -11.427 | |

Note: * denotes 1% level of significance.
Source: Authors' estimation.

**Table 3: J. J. Cointegration Test**

| **Null Hypothesis No. of CS(s)** | **Trace Statistics** | **5% critical values** | **Max. Eigen Value Statistics** | **5% critical values** |
|---|---|---|---|---|
| None * | 63.227 | 59.061 | 33.171 | 30.961 |
| At most 1 | 34.056 | 38.175 | 19.253 | 21.159 |
| At most 2 | 15.804 | 20.276 | 9.246 | 14.797 |

Note: * denotes 1% level of significance.

Source: Authors' estimation.

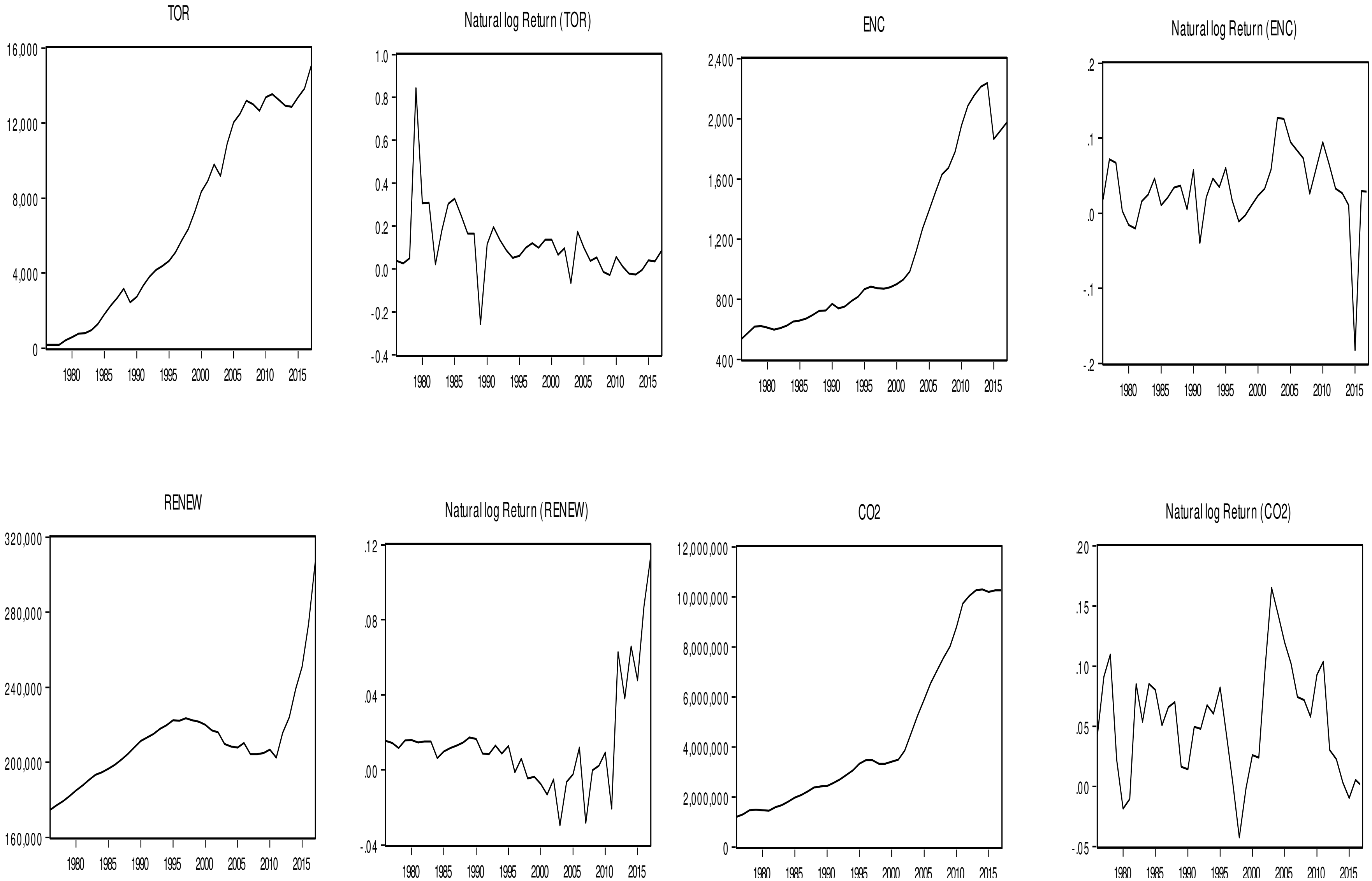
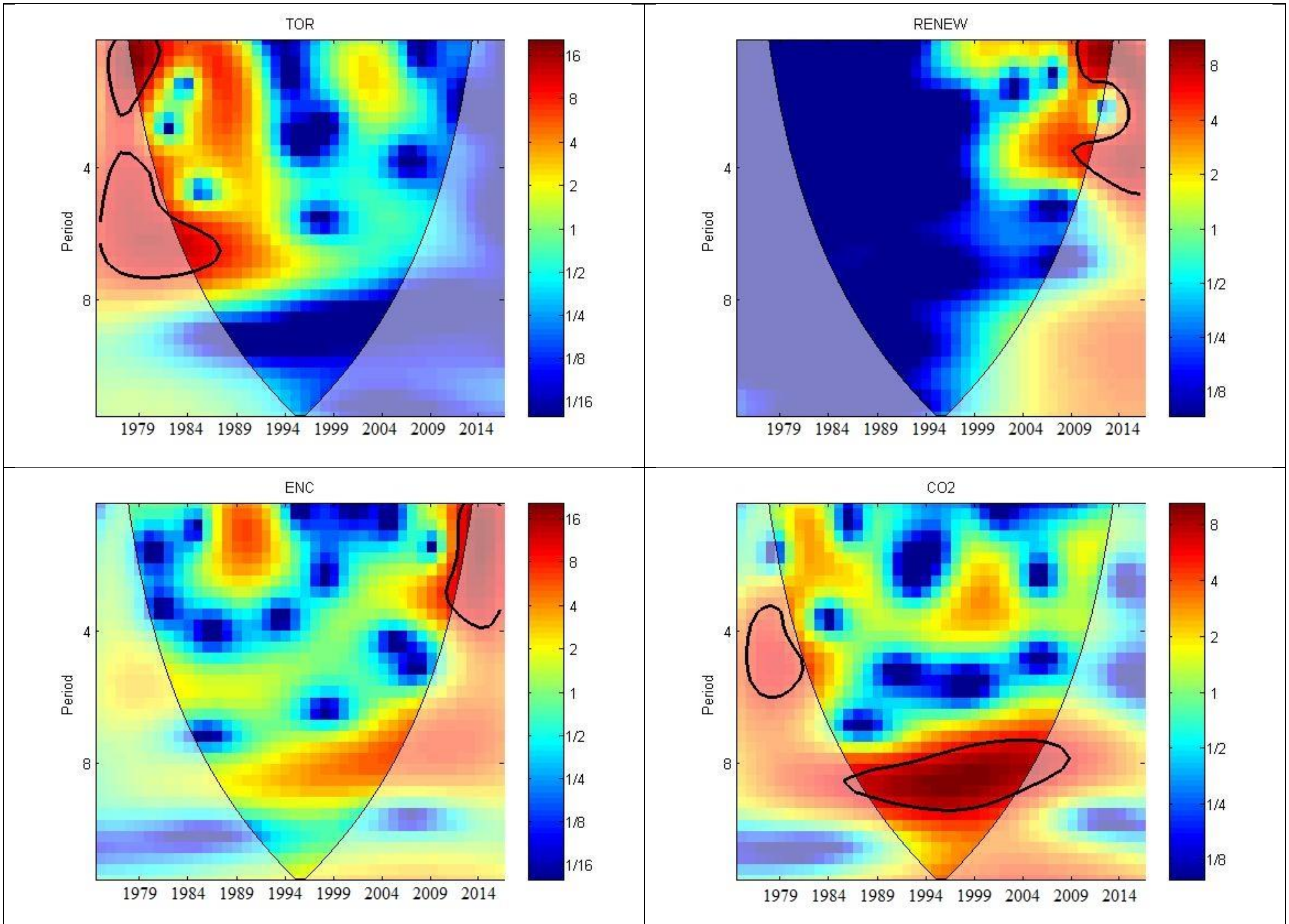
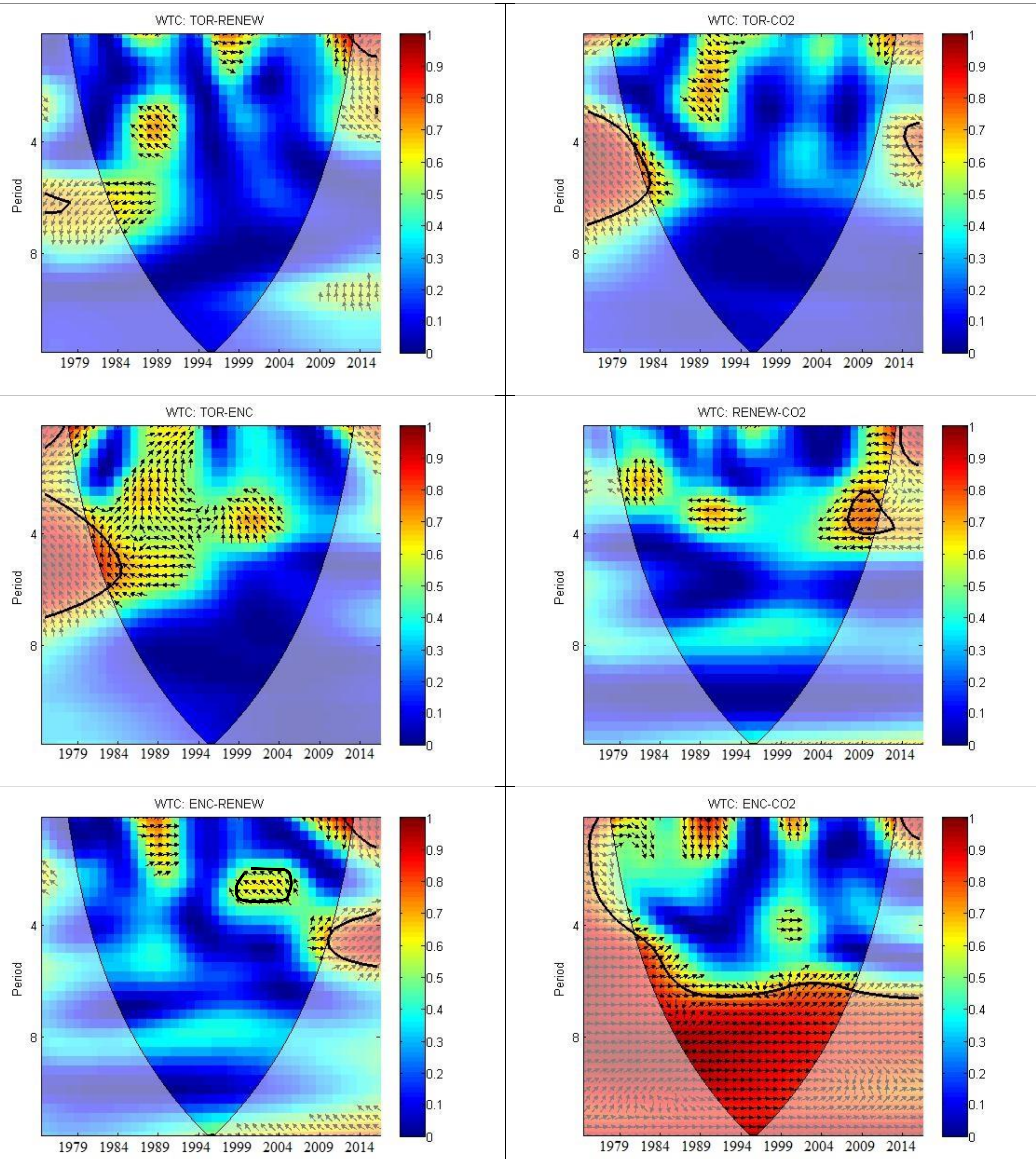



**Figure 1: Actual and Natural log return series of TOR, ENC, RENEW & CO2**




*Note: The thick black contour represents the 5% significance level against the red noise. The colour code for power ranges from blue (low power) to red (high power).*

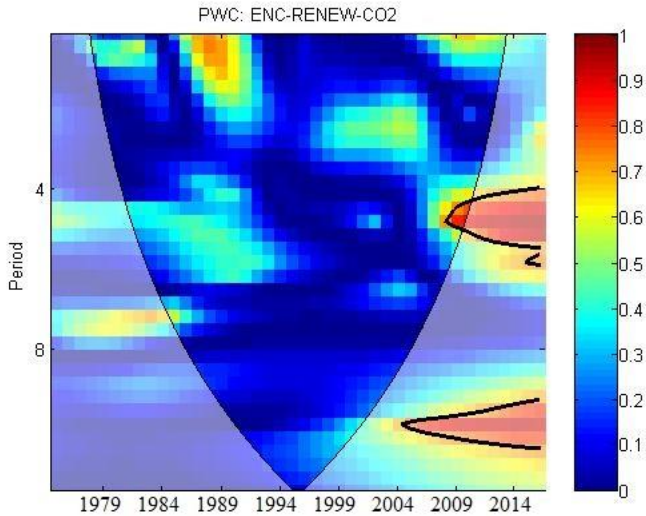
**Figure 2: Continuous Wavelet Transform of TOR, RENEW, ENC & CO2**



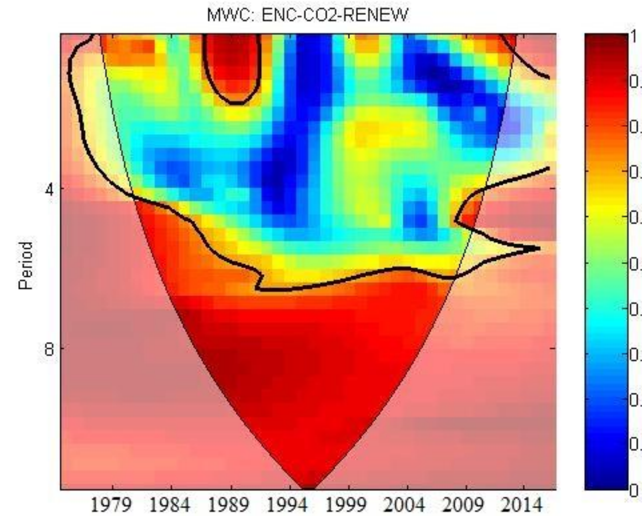

*Note: The thick black contour represents the 5% significance level against the red noise. The colour code for power ranges from blue (low power) to red (high power).*

**Figure 3: Continuous Wavelet Transform of TOR, RENEW, ENC & CO2**

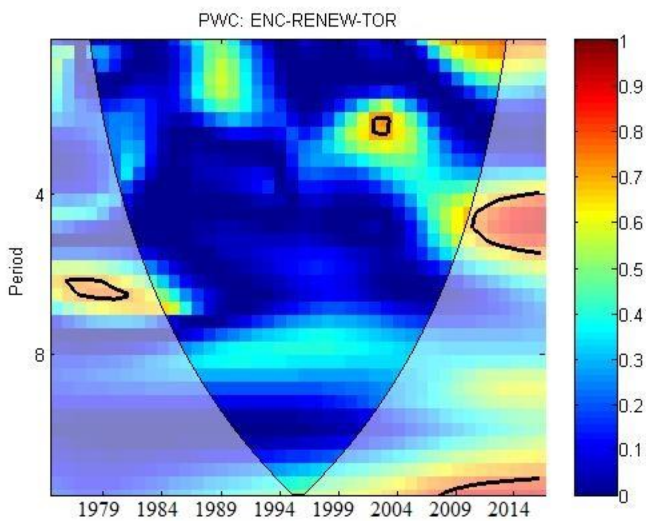
4(a)



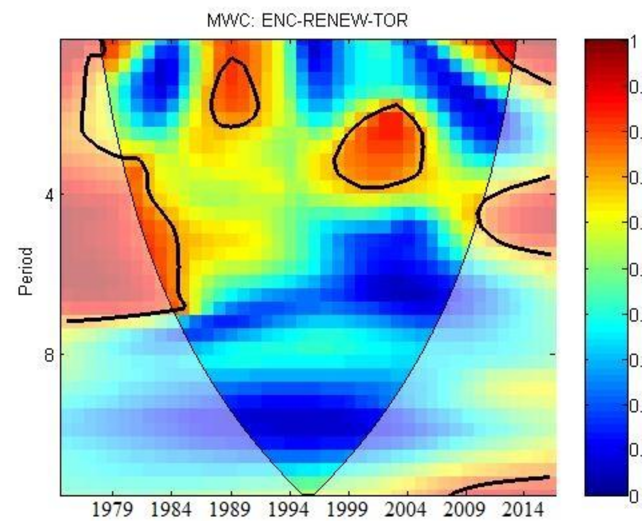

4(b)



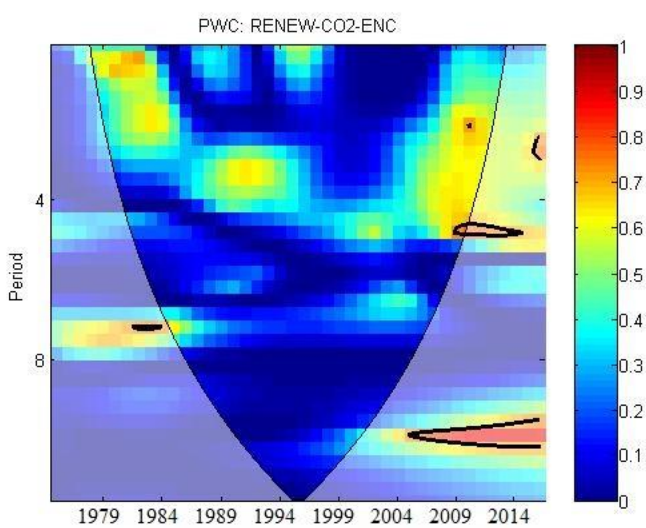

4(c)



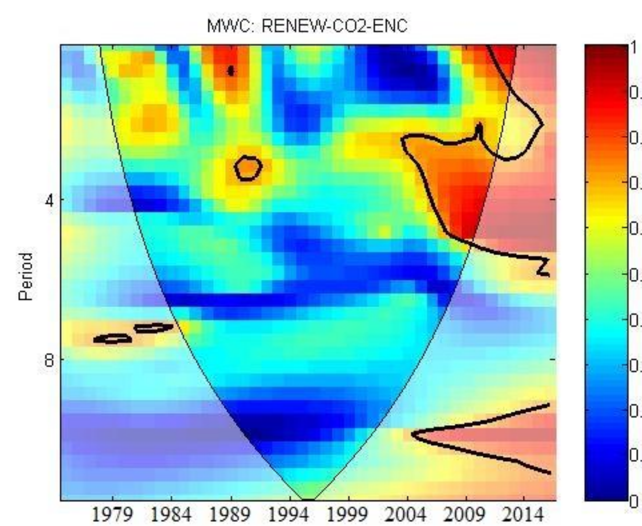

4(d)



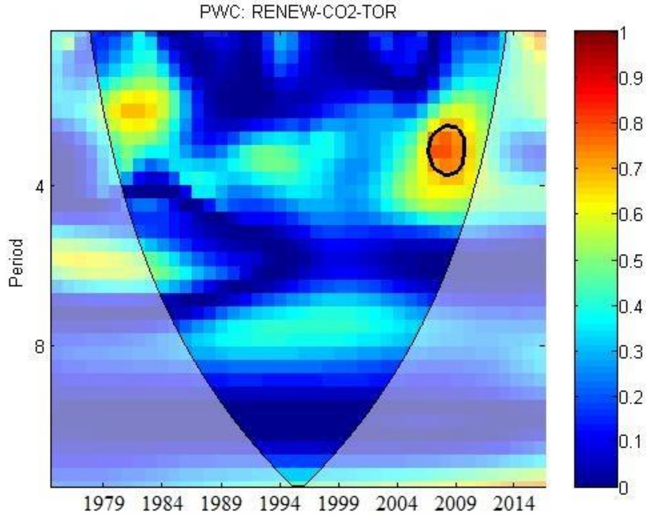

4(e)



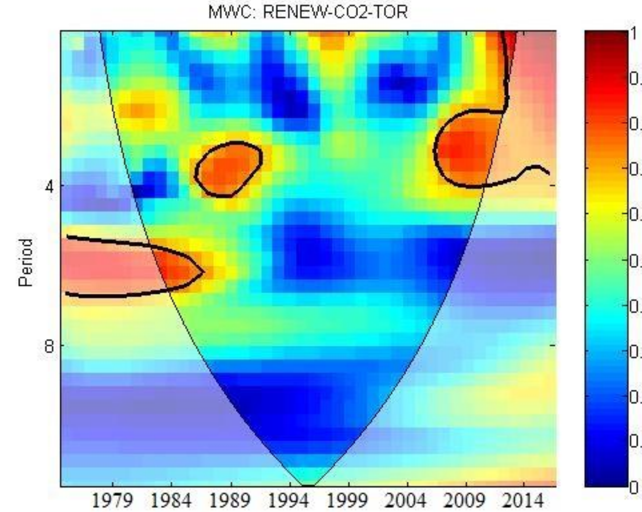

4(f)



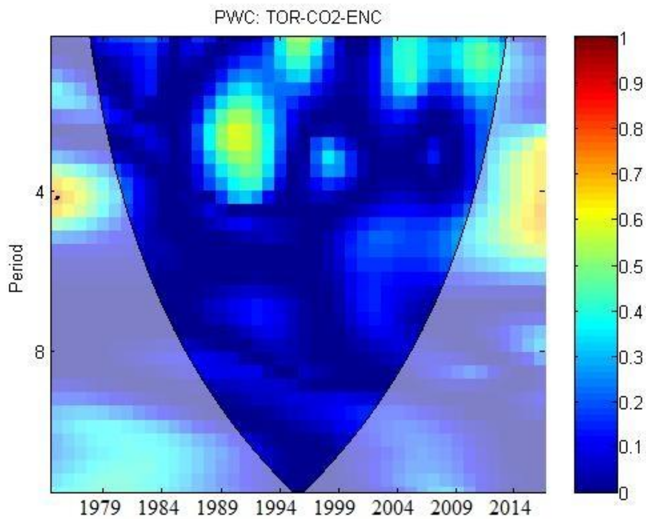
4(g)



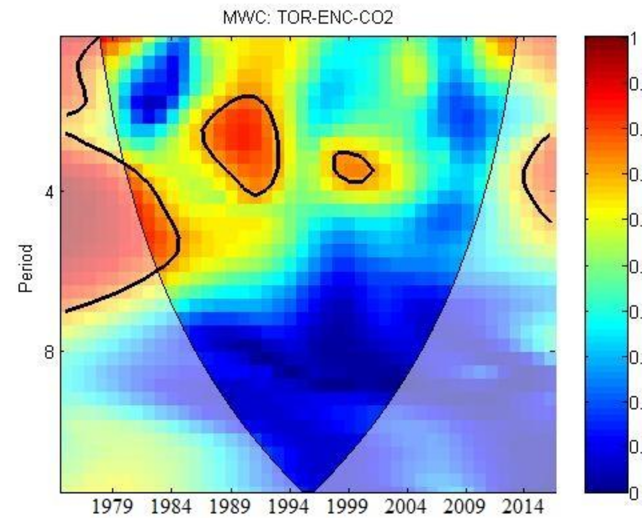

4(h)



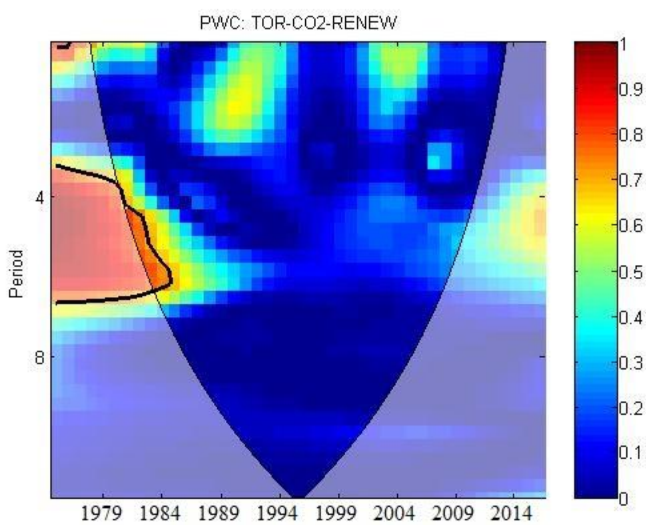

4(i)



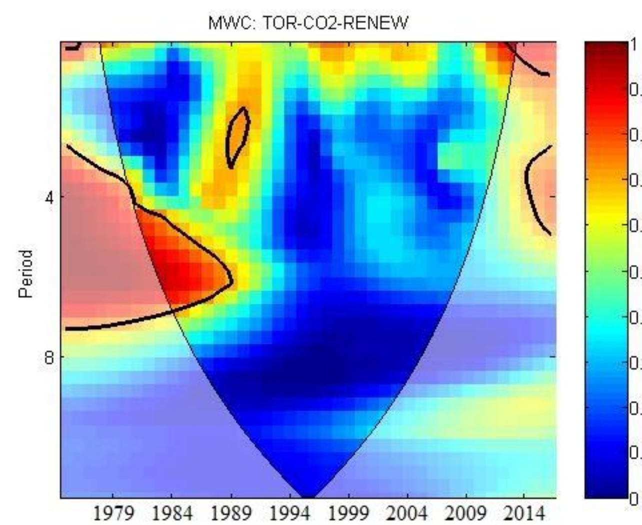

4(j)




4(k)




4(l)



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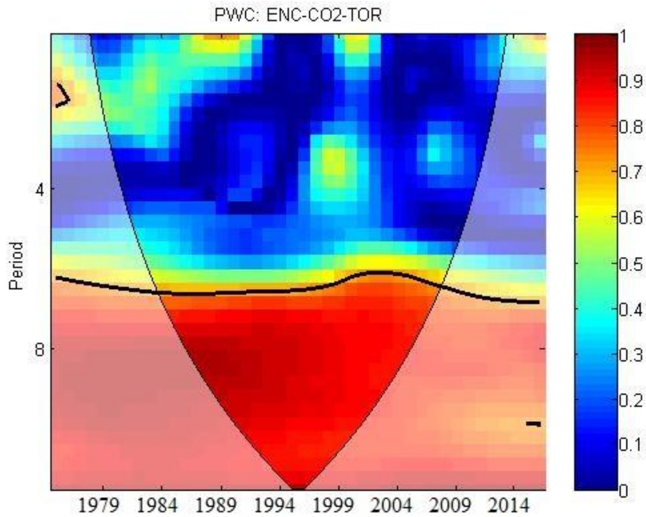
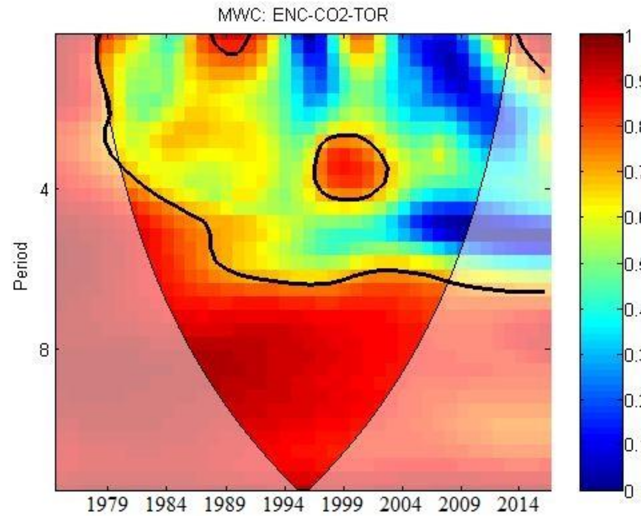
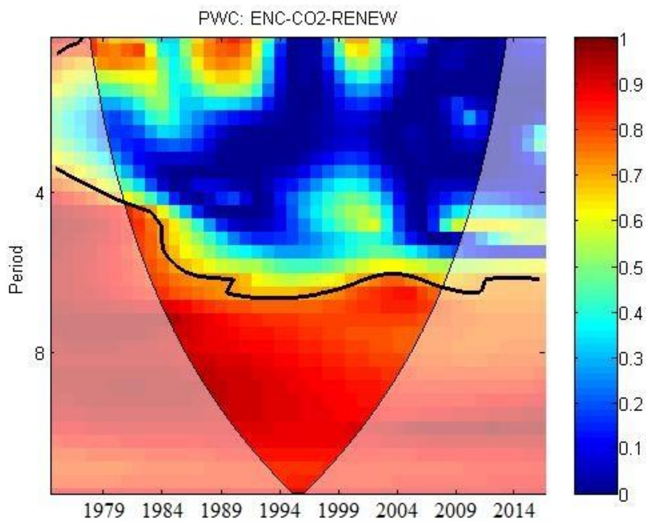


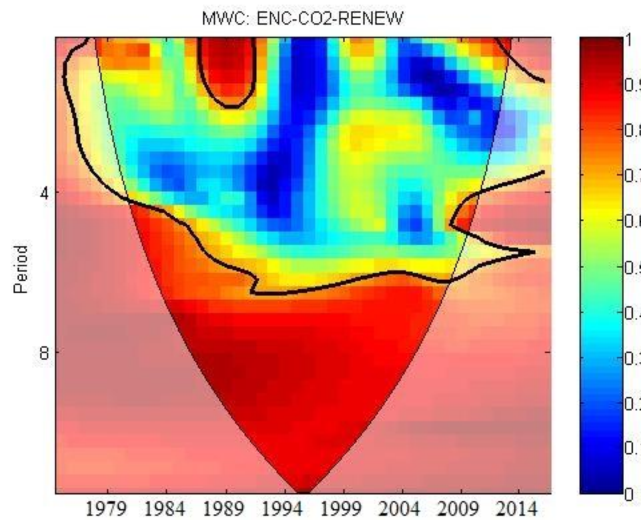

4(n)



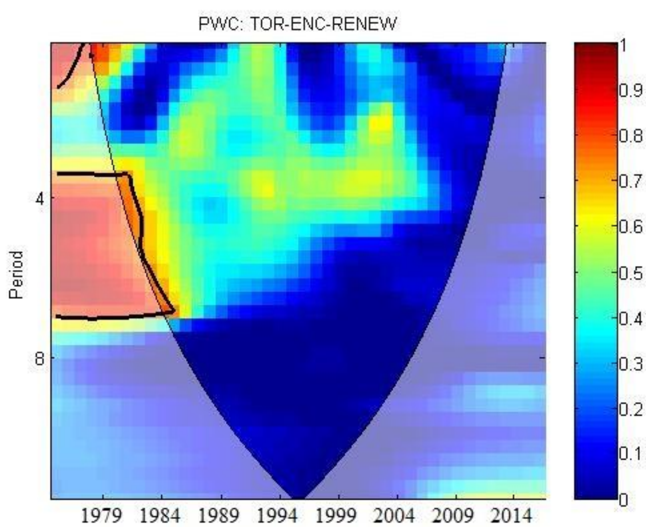

4(o)



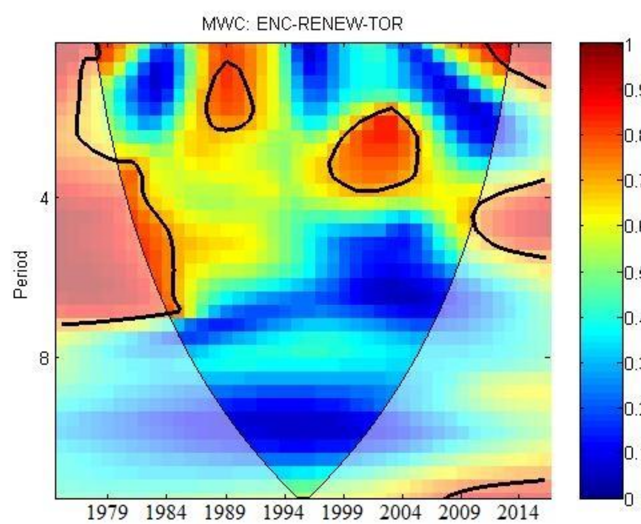

4(p)



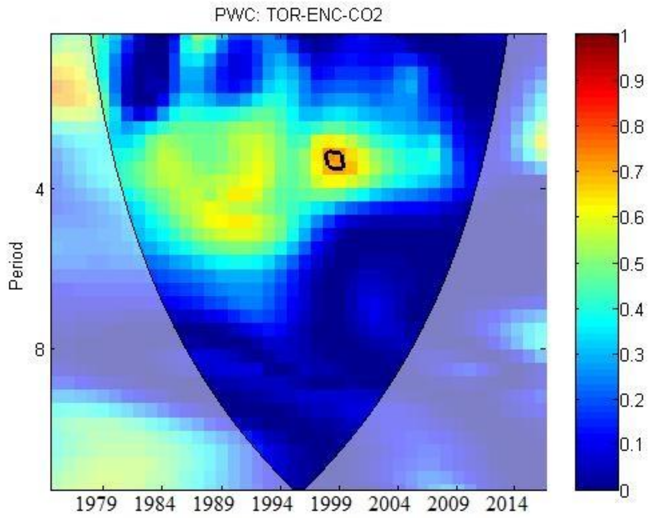

4(q)



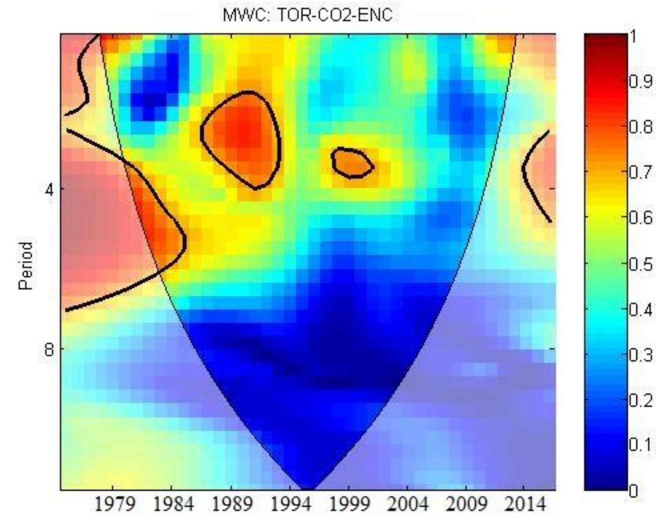

4(r)



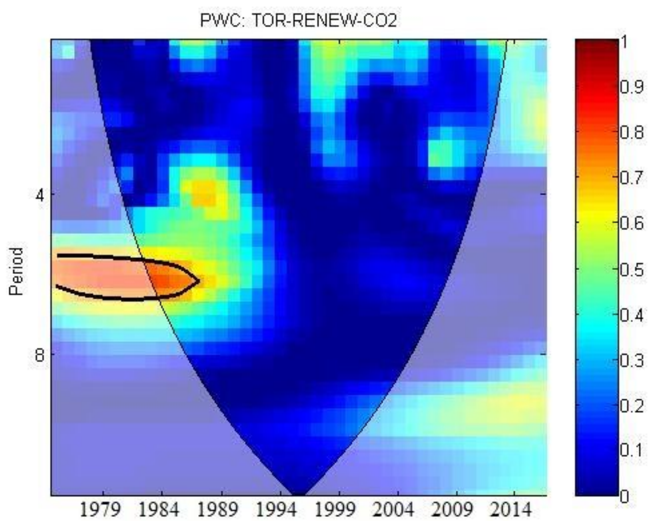
4(s)



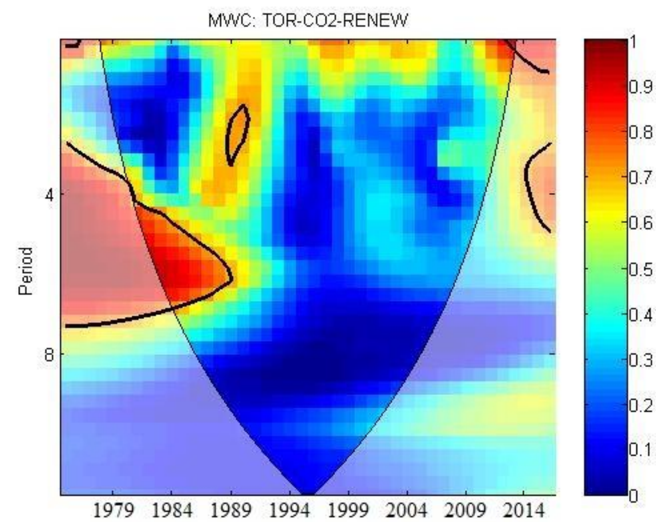

4(t)



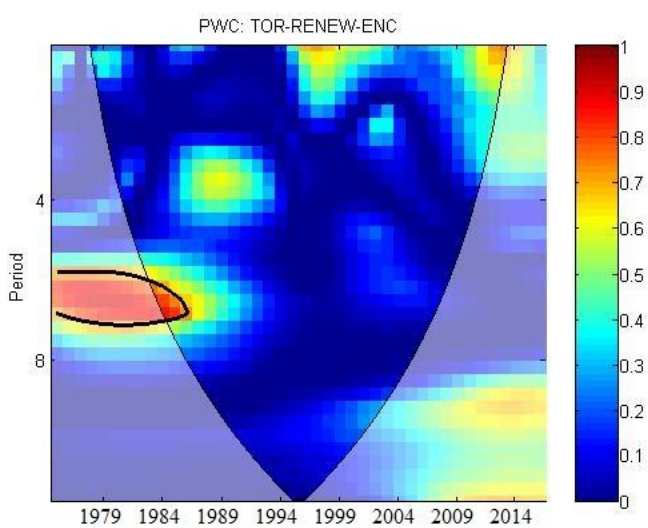

4(u)



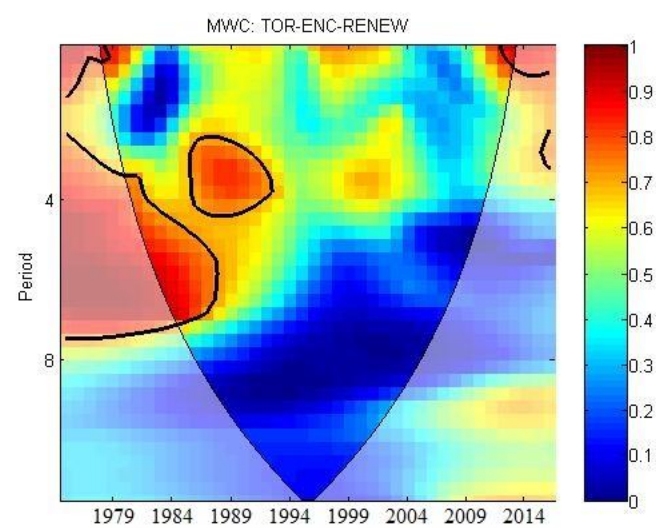

4(v)




4(w)




4(x)




*Note: See Figure-3*

**Figure 4: Partial and Multiple Wavelet Coherences of TOR, RENEW, ENC, CO2**