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ARE RENEWABLE ENERGY AND GLOBALIZATION VITAL FOR ENVIRONMENTAL SUSTAINABILITY IN INDIA? EVIDENCE FROM VECM AND TIME FREQUENCY ANALYSES

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ABSTRACT

Over years, the question of whether the globalization can be a solution or a contributor to environmental deterioration has been a subject to an important debate in academic and policy-making circles. While this relation has been extensively investigated in the case of high-income nations, the evidence on the implications of globalization on environmental sustainability lacks from the prospective of low or middle-income nations. Therefore, this study aims to analyze the dynamic effect of globalization and renewable energy consumption on the environmental sustainability in India by utilizing annual time series data spanning the period 1990-2018. After identifying the series order of stationarity by utilizing ADF and PP tests, this study makes use of VECM and WTC models. The reason is that VECM is powerful method in testing the dynamic shocks among the variables. In addition, the VECM is the powerful in variance decomposition and the possibility of observing long run forecast. The WTC model on the other hand allows us to detect the time frequency dependency among the underlying variables. The results disclose that environmental quality reacts negatively to renewables while the globalization and economic growth seem positively impact the degradation of the environment. These outcomes are expected and consistent with relevant theories and some empirical findings. Although India has recently implemented a wide range of energy policies to promote renewables, however huge challenges still persistent and many efforts are required. Therefore, future policy should enhance the development of renewables and create more competitive environment for the investment in the renewable energy market.

Keywords: India, VECM, WTC, globalization, renewable energy, and ecological footprint

JEL Codes: Q53, Q56, Q57, R11, F14, F17

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YENİLENEBİLİR ENERJİ VE KÜRESELLEŞME HİNDİSTAN'DA ÇEVRESEL SÜRDÜRÜLEBİLİRLİK İÇİN ÖNEMLİ Mİ? VECM VE ZAMAN FREKANS'TAN BİR KANIT

ÖZET

Küreselleşmenin bir çözüm mü yoksa çevresel bozulmaya katkıda bulunan bir unsur mu olabileceği sorusu, akademik ve politika yapıcı çevrelerde yıllardır önemli bir tartışma konusu olmuştur. Bu ilişki, yüksek gelirli ülkeler örneğinde kapsamlı bir şekilde araştırılmış olsa da, küreselleşmenin çevresel sürdürülebilirlik üzerindeki etkilerine ilişkin kanıtlar, düşük veya orta gelirli ulusların geleceğinden yoksundur. Bu nedenle, bu çalışma, 1990-2018 dönemini kapsayan yıllık zaman serisi verileri kullanarak yenilenebilir enerji kullanımı ve küreselleşmenin Hindistan'daki çevresel sürdürülebilirlik üzerindeki dinamik etkisini analiz etmeyi amaçlamaktadır. ADF ve PP testleri kullanılarak serilerin durağanlık sıralaması belirlendikten sonra bu çalışmada VECM ve WTC modelleri kullanılmıştır. Bunun nedeni, VECM'nin değişkenler arasındaki dinamik şokları test etmede güçlü bir yöntem olmasıdır. Ayrıca VECM, varyans ayrıştırmasında güçlüdür ve uzun vadeli tahminleri gözlemleme olasılığıdır. WTC modeli ise, temel değişkenler arasındaki zaman frekansı bağımlılığını tespit etmemizi sağlar. Sonuçlar, çevresel kalitenin yenilenebilir kaynaklara olumsuz tepki verdiğini, küreselleşme ve ekonomik büyümenin ise çevrenin bozulmasını olumlu etkilediğini ortaya koymaktadır. Bu sonuçlar beklenir ve ilgili teoriler ve bazı ampirik bulgularla uyumludur. Hindistan son zamanlarda yenilenebilir enerjileri teşvik etmek için çok çeşitli enerji politikaları uygulamış olsa da, yine de büyük zorluklar devam ediyor ve birçok çaba gerekmektedir. Bu nedenle, gelecekteki politika yenilenebilir enerjideki gelişmeyi arttırmalı ve yenilenebilir enerji piyasasına yatırım için daha rekabetçi bir ortam yaratmalıdır.

Anahtar Kelimeler: Hindistan, VECM, WTC, küreselleşme, yenilenebilir enerji ve ekolojik ayak izi

JEL Kodları: Q53, Q56, Q57, R11, F14, F17

INTRODUCTION

Today the climate changes and global warming are the most notable menace pervade the earth planet, the unprecedented level of carbon emissions cause a direct threat to humans and other species. This is clearly seen in what is running out today in the world, the wildfire that has ingulfed Turkey, Italy, Algeria and Greece, the huge flooding that immersed India, China and Germany, the snow-thaw in the Atlantic, despite their human and economic cost of these tragedies, collectively all of them indicate the disturbance of ecosystem. Many researchers and practitioners have claimed that the nations in their endeavor towards economic growth consuming a high percentage of fossil fuels, such as oil, coal, and natural gas. These types of energy have an adverse impact on the sustainability of environment, and as the economy’s growth must persist to keep the lives on, human beings are presently confronted by two major challenges; accomplishing high rate of economic growth and preserving the environment (Ulucak, and Ozcan, 2020; Adebayo and Kirikkaleli, 2021; Uddin et al., 2017). *What is the solution to this dilemma then?*

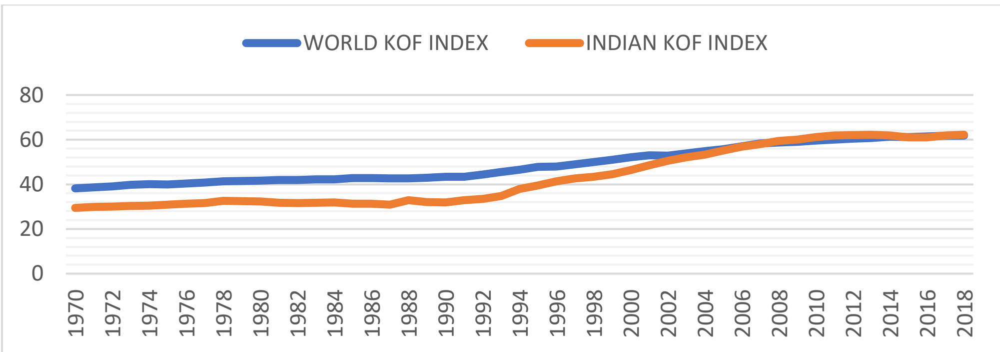
As the consequences of environmental degradation became more sever, nations have started to seek for alternative energy sources in a way that preserve the environment and keep the economy's growth persistent. In this regard, the renewable and clean energy such as hydro energy, biofuels, wind, geothermal, nuclear energy, and solar energy have become a subject of study in the literature of energy and environmental economics. *Are renewables effective in preserving the environment and maintaining a constant economic growth?* A huge number of research have been conducted to answer a such question; however, the results are mixed and inconclusive.

In addition, most of these studies have relied on aggregated dataset on renewable energy, see for instance, Zafar et al., (2021), Umar et al., (2021), Shahbaz et al., (2019), Wang, (2019), Solarin et al., (2018), Bilgili et al., (2016), Sarkodie et al. (2020), Ahmed et al., (2016), Adewuyi and Awodumi (2017), Gao and Zhang (2021) and Sulaiman and Abdul-Rahim (2020). The aggregated data, however, does not clearly identify their respective distinct impact on the environment. In addition, most of these studies have relied only on carbon dioxide emissions (CO_2) to evaluate the environmental damage. *Is CO_2 adequate measure to environmental sustainability?* Solarin and Bello, (2018) argued that CO_2 relates only to air pollution and excludes other pollutants impacting on soil, forests, and other environmental aspects. Therefore, the use of carbon dioxide as an indicator for environmental quality seems to be inadequate measure. Ecological footprint is comprehensive and widely used as an index for environmental sustainability. It consists of six components of surface productive areas: carbon footprint, fishing ground, build-up, forest land, cropland, and grazing land. A part of the discussion on the causes of environmental degradation, the term of globalization has been introduced by many studies as a contributor to environmental deterioration directly or indirectly (Khan et al., 2019). Over decades the worldwide integration of economies and communities has been the most burning subject in the literature of international economics.

Although, there is no consensus on single and appropriate definition of globalization, but mostly, the term globalization refers to the integration of economies of the world through unrestrained trade and financial flows as well as through mutual industrialization and exchange of technology and knowledge (Ray, 2012). The trade flows and industrialization require a huge volume energy which adversely impact the quality of environment. However, the exchange of technology and knowledge can lead to environmental sustainability by implementing advance and efficient technology in an industrial sector. Therefore, it widely believed that globalization can be a solution or a contributor to environmental deterioration. *Does globalization promote environmental sustainability and economic growth in India*?

Many arguments have been observed in literature on which one leads another, globalization, or economic development. Most of researchers argue that the relationship may be akin to the chicken and egg problem, however, there is wide belief that globalization can strongly lead to development. Although a huge number of research have been conducted in this subject, however, the researchers even did not agree on specific index of globalization. For instance, AhAtil et al., (2019) and Zaidi et al., (2019) used Dreher (2006) overall globalization index to examine how globalization impact the CO_2 emissions in China and Asia pacific, respectively. Adebayo and Kirikkaleli, (2021), Liu et al., (2020), Kalayci, (2019) employed the KOF Index globalization to figure out the dynamic effect of globalization on quality of environment in Japan, G7 and NAFTA countries respectively. But notably, KOF index is mostly used in the literature. The KOF index is firstly introduced by Dreher (2006) and updated in Dreher et al., (2008). It measures the globalization through 43 variables, the old version measures the globalization based on 23 variables. The KOF index takes into consideration economic, social, and political aspects for every country. Like most of the other emerging economies, India is experiencing a tremendous increase in globalization index since 1986s. This can be seen obviously in figure 1. The KOF globalization index reveals a persistent increase in globalization from 1988 up to 2018.

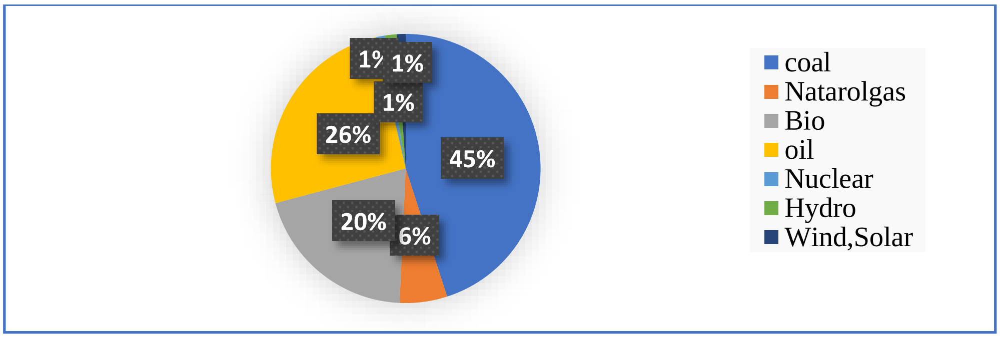
Figure 1: Comparison of the Indian globalization index to average of the world index.



Source: KOF Swiss Economic Institute**:** http://www.kof.ethz.ch/globalisation/

An overview to the Indian energy sector, the fossil fuel represents more than 77 percent from the total energy, in other words, the share of renewable energy is less than 24 percent (see figure 2). Although the hydro energy is obviously witnessing a considerable development since 1990, however, renewables are relatively constituting small part of the total energy. With the increasing non-renewables, the pollution is also increasing in India. Based on the reports released by the International Energy Agency, India is the third largest pollutant country after China and united states in terms of carbon dioxide emissions. *Can the transformation to the renewable energy maintain the environmental quality in India?*

Figure 2: Total Energy Consumption in India in 2018.



Source: International Energy Agency: **https://www.iea.org/countries/india**

To addressing all thses question, this study emprically ivestigates the dynamic effect globalization and reusable energy on the quality of environment in India by utilizing disaggregated annual data of reusable energy mainly hydro energy, nuclear, wind and solar, and KOF globalisation index, spanning period 1990-2018. The merit of this study is twofold: fristly, instead of just applying different methodologies for different countries with different time horizons, this study employs both VECM and Morlet wavelet transformation (WTC). The VECM model allows us to observe the dynamic reaction to the shocks of each endogenous variable in the system. The VECM is also the powerful in variance decomposition and the possibility of observing long run forecast. The WTC model on the other hand allows us to detect the time frequency dependency and causality among the variables. To the best of our knowledge, these two methods altogether have never been used in the literature to study the subject of renewable energy-environmental sustainability nexus. Second, as the environmental deterioration become more sever, the global debate is centered on the issue of global warming and climate change to provide a scientific solution to help the policy makers, in this vein this study contributes to this international debate with the emphasis on the Indian economy and environment.

The rest of the research is organized in the following manner: part II reviews important literature on the subject. Part III presents the research methodology. Part IV shows the results and discussion while the last section provides the conclusion.

I. LITERATURE EVALUATION

Over years, the topic of energy consumption-environmental quality nexus is highly debated in the literature and has taken the attention of researchers and policymakers. Many studies have been conducted to examine these relations, even though the results are mixed and inconclusive. Ozturk (2010) outlined that utilizing different dataset and employing different econometric methods, in addition to differences in the countries' characteristics are the main reasons behind these conflicting outcomes. In this part, we present the possible existing theoretical and empirical studies on the subject. Based on the objectives we have divided these studies into two categories: Firstly, we summarized the studies on the renewable and nonrenewable energy-environmental quality nexus, and studies on the globalization - environmental quality. Second, we outlined the studies on economic growth- environmental quality nexus.

A. ENERGY CONSUMPTION, GLOBALIZATION, AND ENVIRONMENTAL QUALITY NEXUS

In the literature of environmental economics, it is widely believed that non renewables such as fossil fuel natural gas contribute to the environmental degradation, while renewables and clean energy are helpful in reducing the deterioration of the environment. Although researchers extensively examined this general and theoretical plausibility, but no consensus can be observed. For instance, Zafar et al., (2021) investigated the impact of renewable energy on environmental degradation in Asia-Pacific countries. They concluded consisting outcome with theoretical belief, in that biomass energy usage mitigates environmental damage. Wang, (2019) also reached to the same outcome when checked out the effect of biomass energy consumption on environmental pollution in BRICS countries.

But unlike the previous studies, Shahbaz et al., (2019) found that biomass energy consumption contributes to CO_2 emissions when investigating the factors influencing CO_2 using the generalized method of moments. Muhammad (2019) investigated the association among energy consumption, CO_2 emissions, and economic growth in the MENA countries and concluded that higher energy consumption degrades environmental quality in the long run. Solarin et al., (2018) concluded that biomass energy consumption increases carbon emissions in both developed and developing countries. Syed et al., (2021) utilized asymmetric ARDL method to study the dynamic effect of nuclear energy on the environmental quality in India, they concluded that in the long run nuclear energy is effective and helpful in the reduction of carbon emissions so does mitigating the environmental pollution. Obobisa et al., (2021) also found similar results when they tested the impact of geothermal, wind, solar, and biomass on the environmental sustainability in China, by employing DOLS and ARDL methodologies.

Bilgili et al., (2016) found a negative causality from renewables to CO_2 emissions. Sharif et al. (2020) found that renewable energy improves environmental quality in the long run when they tested the impact of energy consumption on Turkey's ecological footprint over the period 1965–2017 and, by employing Quintile ARDL method. Alola et al., (2019) investigated the dynamics impact of energy consumption on ecological footprint in a panel of 40 European countries. Their findings of the panel mean group and ARDL demonstrated that non-renewable energy consumption depletes environmental quality, while renewable energy consumption also not improving ecological sustainability. Destek and Aslan, (2020) studied the implications of Hydroelectricity, wind, solar and biomass on the carbon dioxide emissions in G-7 countries, by following Panel bootstrap causality techniques, their outcomes provide evidence in the favor of environmental sustainability. Hassan et al, (2020) also outlined similar findings when examining the influence of nuclear energy on CO2 emissions in BRICS countries by utilizing CUP-FM, CUP-BC techniques.

Rahman, M. M., & Alam, K. (2021), applied autoregressive Distributive Lag (ARDL) bounds test and the Toda-Yamamoto Granger causality test to study the effect of clean energy on the quality of environment in Bangladesh, they reported that the use of clean energy improved the environmental quality. Saidur, et al (2011) in their comparative study reported that wind source of energy will decrease the degradation of environment. Forbes, K. F., & Zampelli, E. M. (2019) examined the effect of wind energy on carbon emissions from electricity generation in Ireland by employing time series econometric model, their result discloses that higher wind energy penetration levels substantially reduce emissions. Hernandez et al., (2014) estimated the environmental benefit of using solar energy, the concluded that increasing the environmental compatibility of utility-scale solar energy systems will maximize the efficacy of this key renewable energy source in mitigating climatic and global environmental change.

Gao and Zhang (2021) used conventional methodology to study the link between biomass energy use and emissions for developing Asian countries. Their study results show a positive relationship between biomass energy and carbon emissions. Sulaiman and Abdul-Rahim (2020) also tested the impact of biomass clean energy on carbon emission in selected African countries. The empirical findings reveal that clean biomass energy use decreases CO_2 emission in the long run. But the effect of biomass energy consumption on CO_2 emission is insignificant in the short run. The results imply that CO_2 emission can be decreased by increasing clean biomass energy in the energy mix of these selected African countries.

Adebayo and Kirikkaleli, (2021), followed wavelet analysis to study the relationship between globalization and environmental quality in Japan. They concluded that globalization contributes positively to deterioration of the environment. You and Lv, (2018) also concluded the same outcome when they examined the possible impact of globalization on the quality of environment in selected 83 countries. But unlike the previous studies, Liu et al., (2020) found somehow different results in G7 countries. They found that although initially globalization deteriorates environmental quality, however, in long-run it decreases the deterioration of environment. Kalayci, (2019) also tested the impact of globalization on the environment in NAFTA countries and concluded that globalization increases carbon dioxide emissions. Van and Bao (2018) also concluded the same finding, when testing the globalization-environment nexus by utilizing ARDL model in Vietnam.

More recently, a huge number of studies have investigated this relation see for instance Nguyen and Le, (2020); Pata, (2021); Aslam et al., (2021); Khan et al., (2019); Yurtkuran, (2021); Zaidi et al., (2019); AhAtil et al., (2019); Khan et al., (2019), most of these studies have reached to the same conclusion that globalization contributes positively to environmental deterioration. Notably, in case of India almost no study addressed this subject, and the huge limitation of available studies can be seen in the traditional methodologies that have been utilized, in addition to that, CO_2 emissions has been mostly used as a measure to the quality of environment.

B. ECONOMIC GROWTH AND ENVIRONMENTAL POLLUTION NEXUS

The primary goal of economic activities is to increase human welfare and rapid economic growth is seen to accomplish this goal. However, with the increase in production, wastes generated by the production and consumption process increase the environmental cost. If economic growth occurs, the consumption of natural resources exceeds production capacity, which lead to an increase in the amount of waste and greenhouse gas emissions (Pata, 2018). Therefore, human beings are currently confronted by two major challenges; achieving economic growth and protecting the environment (Uddin et al., 2017). When the economy starts moving along the growth path then at the earliest stage of the economic growth environment deteriorate due to air pollution, deforestation, and many other pollutants. However, with an increase in per capita income economy starts to develop and environmental degradation diminishes (Shahbaz and Sinha, 2018). This relationship between economic growth and environmental pollution is hypothesized to be an inverted U-shaped relationship and is referred to in the literature as the Environmental Kuznets Curve (EKC). The EKC hypothesis was firstly introduced by Simon Kuznets (1956) and later confirmed by Grossman and Krueger (1995). The dilemma of environment and growth has attracted the attention of researchers for many decades. Over the years, studies have tried to figure out the determinants of environmental pollution (Ali et al., 2016). Therefore, several empirical studies have tested the validity of the EKC hypothesis (see for instance, Diao *et al*., 2009; Lacheheb *et al*., 2015; Ben Jebli *et al*., 2015 Moutinho *et al*., 2017; Adu, and Dekyriah, 2017; Katircioğlu and Taşpinar, 2017; Sirag*et al*., 2018; Awad, 2019; Raza *et al.*, 2020), however, there is conflicting outcomes. Most of researchers have argued that the assumption of the EKC is not applicable for developing countries because these countries are still in their early stages of economic development. Thus, these countries have not reached yet to the turning point where the growth can improve the quality of environment Al-Mulali et al., (2015). *Is EKC hypothesis valid in India?*

II. RESEARCH METHODOLOGY

To scrutinize the dynamic impact of the renewables and globalization on environmental quality in India, the current research utilizes annual time series data on ecological footprint, clean and renewable energy basically hydro, nuclear, wind and solar energy, globalization, and economic growth. The period 1990-2018 selected according to data availability. The dataset is transformed to natural logarithm to overcome the problem of extreme values. The full definition of each variable and the sources are given in table 1. Our basic model can be specified as follows:

$$lnEFP_t = \alpha_0 + \alpha_1 lnGDP_t + \alpha_2 lnGLB_t + \alpha_3 lnHYD_t + \alpha_3 lnNUC_t + \alpha_3 lnWSO_t + e_t \quad (1)$$

Table 1: Definition of the variables.

Variable	Definition	Measurement	Source
EFP	Ecological footprint	Global hectares	Global footprint networks
GDP	Economic growth	Per capita real income	World Development Bank
GLB	Globalization	KOF globalization index	KOF Swiss Economic Institute
HYD	Hydro energy	Thousands of ktoe	International Energy Agency
NUC	Nuclear energy	Thousands of ktoe	International Energy Agency
WSO	Wind and solar energy	Thousands of (ktoe)	International energy agency

To achieve the objective of the study this research employs the vector error correction (VECM) model. The VECM model allows us to analyze the dynamic interactions between the shocks of the variables in the VAR system. In addition, the VECM model will be utilized for variance decompositions. In this regard, by following the testing procedures of Singh and Vashishtha (2020), and Nugraha and Osman, (2019) and considering the variables of interest, our basic VAR system can be specified as follows:

$$LnEFP_t = \alpha_0 + \sum_{i=1}^{m} \alpha_1\, LnEFP_{t-i} + \sum_{i=0}^{n} \alpha_2\, LnGDP_{t-i} + \sum_{i=0}^{p} \alpha_3\, LnGLB_{t-i} + \sum_{i=0}^{q} \alpha_4\, HYD_{t-i} + \sum_{i=0}^{g} \alpha_5\, NUC_{t-i} + \sum_{i=0}^{h} \alpha_6\, WSO_{t-i} + \mu_{1t} \quad (2)$$

Where equations 2 is the VAR model and the lag lengths are chosen according to Schwarz information criterion (SIC). The SIC dominates all other criterias such as Akaike information criterion (AIC), Hannan-Quinn information criterion (HQ). And it is generaly used to avoid over-parameterization problem. For the system to return to the long-run equilibrium, the movements of at least some of the variables must respond to the magnitude of disequilibrium. Bilgili, (2003) claims that in any model the error correction would not occur if all adjustment coeffiecients are equal to zero. Therefore, at least one of them should be statistically diffferent from zero. With the normaized cointegration coefficients the vector error correction model (VECM) can be obtained. Based on the study variables the VECM can be generated by the following model:

$$\Delta lnEFP_t = \lambda_0 + \sum \lambda_1 \Delta lnGDP_{t-1} + \sum \lambda_2 \Delta lnGLB_{t-1} + \sum \lambda_3 \Delta lnHYD_{t-1} + \sum \lambda_4 \Delta lnNUC_{t-1} + \sum \lambda_4 \Delta lnWSO_{t-1} + \lambda ECT_{t-1} + e_t \quad (3)$$

Where: $ECT_{t-1} = lnEFP_{t-1} - lnGDP_{t-1} - lnGLB_{t-1} - lnHYD_{t-1} - lnNUC_{t-1} - lnWSO_{t-1}$ (4)

III. RESULTS AND DISCUSSION

In this part of , the discussion to the obtained empirical findings is presented: Firtsly, the investigation of descriptive statistics that measures the dispersion and cenetral tendency is evaluated. Table 2 indicates that renewables mirror the highest average followed by globalisation and economic growth. The ecological footprint which represents the environmental sustainability demonstrates the lowest average. Only economic growth and globalization show negative Skewness. The naromal distribution that evaluated by Kurtosis confirms that all underlying series demostrate normal districution except economic growth and wind-solar energy. Since most of time series data are not stationary in nature, an investigation into the series stationarity properties is vital and indispensable. The results of regression a nonstationary time series variable on another nonstationary time series variable yields often spurious results although there is no meaningful relationship between them. To avoid spurious results such as biased traditional F and t statistics, one should use stationary variables in their levels or difference stationary variables. Stationarity means that the time series has a constant mean, and finite (bounded) variance. A stationary time series tends to frequently to return to the mean value. A nonstationary time series cannot be used in estimation of the model to be used in forecasting (Bilgili, 1998).

In this study the Augmented Dickey-Fuller (ADF) and Phillip-Perron (PP) tests are utilized to test the stationarity of the series. As can be observed clearly in table 3 all the series are tested in their level as well as first-difference. The findings of ADF and PP tests are almost similar since none of the series is integrated at the second order or I(2). A bit deference between the two tests is that ecological footprint, globalization and hydro energy demonstrate stationarity at fisrt difference in ADF test while PP unit root test shows that hydro energy is stationary at level. Furthermore, wind and solar energy is stationary at level as well as first difference in ADF unit root test while in PP test only shows stationarity at first difference. İn general we can state that some of the variables are integrated at level as well as first difference (economic growth, nuclear, wins-solar energy) and some variables are integrated only at first difference. Combing both tests' outcomes we can conclue that our study variables show required level of stationarity to proceed.

Table 2: Descriptive Statistics

	EFP	**GDP**	**GLB**	**NUC**	**WSO**	**HYD**
Mean	0.532581	6.313957	50.99141	4968.586	1815.310	8864.276
Median	0.482296	6.658924	53.24166	4432.000	451.0000	7798.000
Maximum	0.747576	8.845756	62.23346	9991.000	9946.000	12995.00
Minimum	0.373324	1.056831	31.94126	1406.000	10.00000	5969.000
Std. Dev.	0.120419	1.897328	10.61668	2915.934	2590.828	2556.086
Skewness	0.444009	-0.872084	-0.464001	0.585490	1.724252	0.269023
Kurtosis	1.731000	3.194608	1.760674	2.042385	5.227603	1.420853
Sum	15.44486	183.1048	1478.751	144089.0	52644.00	257064.0

Table 3: Stationarity tests

Variables	I(0)	I(I)	Decision
Dickey–Fuller (1979) (ADF) unit root tests			
LnGDP	-4.952226*	-5.597706*	I(0) I(I)
LnEFP	-1.628954	-5.618342*	I(I)
LnGLB	-2.360672	-3.416252***	I(I)
LnHYD	-2.539435	-6.054306 *	I(I)
Ln NUC	-3.311829***	-8.508420 *	I(0) I(I)
LnWSO	4.434090*	4.048280 *	I(0) I(I)
Phillips and Perron unit root test			
LnGDP	-4.347377*	-14.48477*	I(0) I(I)
LnEFP	-1.649357	-5.678876*	I(I)
LnGLB	-2.610627	-3.309941***	I(I)
LnHYD	-2.539435***	-6.054306*	I(0) I(I)
Ln NUC	-3.392580***	-8.961545*	I(0) I(I)
LnWSO	14.24878*	-2.022161	I(0)

Note: 1% 5% 10% level of significance are illustrated by *, ** and *** correspondingly

After presenting the stationarity properties, the study moves to explore the cointegration relationship among the underlying variables. The concept of or cointegration was firstly introduced by Engle and Granger (1987) to investigate the relationship between a set of variables within a dynamic framework in long-term. Nkoro and Uko, (2016) claims that cointegration illustrates the existence of a long-run equilibrium among underlying economic time series that converges over time and provides a stronger statistical and economic foundation for empirical error correction model. Therefore, the cointegration test cannot be overlooked to confirm the long run meaningfulness of the model. If no meaningful relationship is found, then the model is spurious and will give misleading outcomes and it becomes imperative to continue to work with variables in differences instead.

Table 4 outlines the cointegration test outcomes. This study makes used of Johansen cointegration method. It shows that there exists long-run relationship among our study series since the Trace and the Max-Eigen Statistic values are less that Critical Value (0.05). The significance of coefficients' test in table 5 also confirm the findings of table 4. The standard errors in table 4 indicate that all coefficients are statistically significant. The single cointegration or long run equilibrium of economic growth, globalization, and renewables with respect to environmental sustainability is given in by equation 5. One important note is that the logical specification of error correction model (see equation 4) presents the result in opposite, so they should read inversely, in other words, the negative should read as positive and vice versa.

$$LnEFP = 1.100275LnGDP + 2.691604\text{LnGLB} - 0.567597\text{LnHYD} - 1.134603\text{LnNUC} - 0.977483\text{LnWSO} \quad (5)$$

The results in equation 5 indicate that the globalization and economic growth in India contribute positively to environmental degradation. However, the clean and renewable energy such hydro, nuclear, wind and solar help decrease the deterioration of the environment in India. The magnitudes are shown within the equation. These findings are expected and consistent with many findings in the literature. The adjustment coefficients indicate the short run dynamics. They show the speed of adjustments of the variables in response to a standard deviation from long run equilibrium. The speed of adjustment is seen to facilitate long-run convergence among the parameters with a significant and negative error correction term (ECT) coefficient, the result of ECT is -0.016514, which presents the evidence of cointegration among the parameters, and this signifies the capability of the model to witness a 0.0165% speed of adjustment to verify the tendency to equilibrium in the long-term. Equation 6 shows the short run dynamics of environmental sustainability (EFP), which is first equation of VECM (see table 6). The signs of cointegration and adjustment coefficients are almost the same as in table 4. With little differences in coefficient values, the short run and long run did not change obviously.

$$D(LnEFP) = -0.016514[\text{LnEFP}(-1) + -1.100275\text{LnGDP}(-1) + -2.691604\text{LnGLB} + 0.567597\text{LnHYD} + 1.134603\text{LnNUC} + 0.977483\text{LnWSO}] - 0.463351\text{D}(\text{LNEFP}(-1)) + -0.009893\text{D}(\text{LNGDP}(-1)) - 0.332724\text{D}(\text{LNGLB}(-1)) + 0.087430LNHYDC(-1) + 0.003126LNNUC(-1) + 0.04731LNWSO(-1) + 0.029351 \quad (6)$$

Table 4: Johansen cointegration test

Trend assumption: Linear deterministic trend (restricted) Unrestricted Cointegration Rank Test (Trace)				
Hypothesized		Trace	0.05	
No. of CE(s)	**Eigenvalue**	**Statistic**	**Critical Value**	**Prob.****
None *	0.929791	189.9140	117.7082	0.0000
At most 1 *	0.848402	118.1944	88.80380	0.0001
At most 2 *	0.607808	67.25825	63.87610	0.0253
At most 3	0.533724	41.98616	42.91525	0.0618
At most 4	0.411463	21.38577	25.87211	0.1637
At most 5	0.230450	7.072644	12.51798	0.3370
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.929791	71.71958	44.49720	0.0000
At most 1 *	0.848402	50.93613	38.33101	0.0011
At most 2	0.607808	25.27209	32.11832	0.2708
At most 3	0.533724	20.60039	25.82321	0.2105
At most 4	0.411463	14.31313	19.38704	0.2338
At most 5	0.230450	7.072644	12.51798	0.3370

1 Cointegrating Equation(s): Log likelihood 232.8937

Normalized cointegrating coefficients (standard error in parentheses)

LOG(EFP)	LOG(GDP)	LOG(GLB)	LOG(HYD)	LOG(NUC)	LOG(WSO)	@TREND(91)
1.000000	-1.100275	-2.691604	0.567597	1.134603	0.977483	-0.269429
	(0.08968)	(0.61498)	(0.33549)	(0.16141)	(0.20264)	(0.03781)

Adjustment coefficients (standard error in parentheses)

D(LOG(EFP))	-0.016514
	(0.01595)
D(LOG(GDP))	0.566688
	(0.26869)
D(LOG(GLB))	-0.009375
	(0.01032)
D(LOG(HYD))	-0.090482
	(0.06136)
D(LOG(NUC))	-0.093545
	(0.15744)
D(LOG(WSO))	-0.159268
	(0.06571)

Note: Trace test indicates 3 cointegrating eq(s) at the 0.05 level. Max-eigenvalue test indicates 2 cointegrating eqn(s) at the 0.05 level

Table 5: Significant tests of the adjustment and cointegrating coefficients

DLnEFP	$\chi2$ (1) 1.370156 (0.241785)	LnEFP	$\chi2$ (1) 0.397602 (0.528330)
DLnGDP	$\chi2$ (1) 4.122267 (0.042322)	LnGDP	$\chi2$ (1) 19.81097 (0.000009)
DLnGLB	$\chi2$ (1) 0.881198 (0.347874)	LnGLB	$\chi2$ (1) 9.090605 (0.002569)
DLnHYD	$\chi2$ (1) 2.067945 (0.150424)	LnHYD	$\chi2$ (1) 1.328373 (0.249095)
DLnNUC	$\chi2$ (1) 0.456436 (0.499294)	LnNUC	$\chi2$ (1) 9.916436 (0.001638)
DLnSWO	$\chi2$ (1) 4.918101 (0.026577)	LnSWO	$\chi2$ (1) 6.570824 (0.010366)

Table 6: Vector Error Correction Estimates

Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1	LOG(GLB(-1))	LOG(HYD(-1))	LOG(NUC(-1))	LOG(WSO(-1))	
LOG(EFP(-1))	1.000000	-2.691604	0.567597	1.134603	0.977483	
LOG(GDP(-1))	-1.100275	(0.61498)	(0.33549)	(0.16141)	(0.20264	
	(0.08968)	[-4.37672]	[1.69183]	[7.02915]	[4.82365	
@TREND(90)	-0.269429					
	(0.03781)					
	[-7.12643]					
C	-3.402027					
Error Correction:	D((EFP)	D(GDP)	D(GLB)	D(HYD)	D((NUC)	D(WSO)
CointEq1	-0.016514	0.566688	-0.009375	-0.090482	-0.093545	-0.159268
	(0.01595)	(0.26869)	(0.01032)	(0.06136)	(0.15744)	(0.06571)
	[-1.03553]	[2.10911]	[-0.90884]	[-1.47460]	[-0.59414]	[-2.42373]
D(LOG(EFP(-1)))	-0.463351	-3.293779	-0.168753	-0.365572	-1.615268	-1.577598
	(0.25562)	(4.30687)	(0.16535)	(0.98356)	(2.52373)	(1.05331)
	[-1.81263]	[-0.76477]	[-1.02056]	[-0.37168]	[-0.64003]	[-1.49775]
D(LOG(GDP(-1)))	-0.009893	-0.124879	0.004354	-0.044326	-0.081947	-0.113046
	(0.01200)	(0.20210)	(0.00776)	(0.04615)	(0.11843)	(0.04943)
	[-0.82470]	[-0.61790]	[0.56111]	[-0.96040]	[-0.69196]	[-2.28711]
D(LOG(GLB(-1)))	-0.332724	1.395662	0.671383	-0.760560	-0.554032	2.049363
	(0.28585)	(4.81613)	(0.18490)	(1.09986)	(2.82215)	(1.17786)
	[-1.16398]	[0.28979]	[3.63097]	[-0.69151]	[-0.19632]	[1.73990]
D(LOG(HYD(-1)))	0.087430	-0.175626	-0.062854	-0.086051	-0.578558	0.150521
	(0.06644)	(1.11935)	(0.04297)	(0.25563)	(0.65591)	(0.27375)
	[1.31600]	[-0.15690]	[-1.46257]	[-0.33663]	[-0.88207]	[0.54984]
D(LOG(NUC(-1)))	0.003126	-0.412398	-0.010180	0.173746	-0.465100	0.066502
	(0.02437)	(0.41063)	(0.01577)	(0.09378)	(0.24062)	(0.10043)
	[0.12825]	[-1.00431]	[-0.64575]	[1.85279]	[-1.93293]	[0.66220]
D(LOG(WSO(-1)))	0.047311	0.267689	0.000584	-0.024825	0.552081	0.141083
	(0.04173)	(0.70309)	(0.02699)	(0.16056)	(0.41199)	(0.17195)
	[1.13375]	[0.38073]	[0.02165]	[-0.15461]	[1.34002]	[0.82048]
C	0.029351	0.085244	0.013571	0.051981	0.036954	0.186247
	(0.01170)	(0.19720)	(0.00757)	(0.04504)	(0.11556)	(0.04823)
	[2.50763]	[0.43226]	[1.79247]	[1.15423]	[0.31979]	[3.86169]

Notes: Determinant resid covariance 1.30E-15. Log likelihood 232.8937. Akaike information criterion -13.17731. Schwarz criterion -10.53764

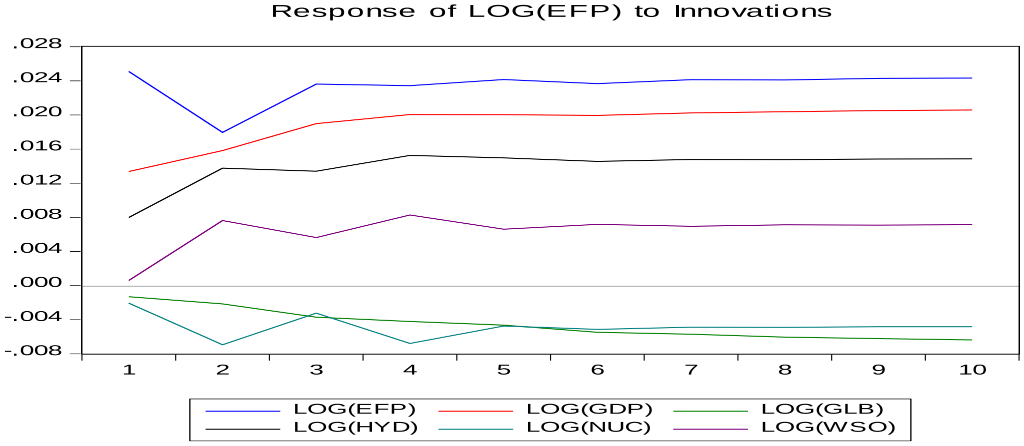
In this part we discuss the relative contribution of economic growth, globalization, and renewables to the fluctuations in environmental quality. This done by analyzing the forecast variance of the environmental quality over different time interval. Table 7 outlines the variance decomposition outcomes which indicate the percentage contribution of innovations in each variable to the change in environmental quality. Variance decomposition indicates that shocks in ecological footprint are important source of variation in environmental sustainability accounting for 100, 87.7758, 87.23114, 84.38212, and 83.71951 percent from first period up to period five respectively. The analysis also indicates that economic growth in terms of GDP is the second largest contributors to the deterioration in environment accounting for 5.044927 in the period two and 8.336377 percent in period five respectively. Furthermore, the variance analysis reveals that the hydro and nuclear energy are the third largest contributors to the fluctuations in environmental quality, and lastly globalization and wind-solar energy demonstrate the lowest percentage during the specified time interval.

The analysis proceeds to the impulse response function. The function exposes the dynamic reaction of ecological footprint to the impulse in the variables in the VAR system. This dynamic process enables us to observe the effect of a unit shock on one variable on present and future values of itself and the other variables. Hence all variables in the system are affected through one standard deviation shock occurred in innovations of any variable in the VAR system. Figure 3 presents the generalized form of impulse response analysis of this study. From up to down the first line indicates the reaction of environmental quality to its own shocks, it shows that EFP decreases sharply for three quarters, then increases steadily till quarter five before it keeps its relatively higher levels for the following periods. The second line exhibits the response EFP to the shocks of economic growth. With the impulse of GDP, EFP increases constantly till quarter five and keeps its relatively higher levels in the following quarters. The third line exhibits the response of EFP to the shocks in hydro energy, EFP increases sharply till quarter three, it declines slowly till quarter five before it increases again. The fourth line presents the reaction of EFP to the innovations in wind-solar energy, EFP show ups and downs till quarter six, before keeps its relatively low level in rest of quarters. The same is true for the shocks in nuclear energy. The shock of globalization seems to have a little negative effect on the sustainability of the environment.

Table 7: Variance Decomposition of LOG(EFP)

Period	S.E.	LOG(EFP)	LOG(GDP)	LOG(GLB)	LOG(HYD)	LOG(NUC)	LOG(WSO)
1	0.025094	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.032933	87.77586	5.044927	0.034412	4.879225	2.074191	0.191385
3	0.041596	87.23114	6.462727	0.223964	4.563381	1.392523	0.126269
4	0.049391	84.38212	7.846943	0.367045	5.315045	1.999062	0.089785
5	0.056167	83.71951	8.336377	0.513097	5.612733	1.746335	0.071946

Figure 3: Impulse response analysis



To catch up the time-frequency dependence among our underlying series this study utilized Wavelet coherence method. Time-frequency deals with the change over time and shows how the relationship varies from one frequency to another. This is very important to understand the movements and dynamics of the variables. This study utilized Morlet wavelet function. Adebayo, (2020) outlined that Morlet wavelet brings balance between phase and amplitude, and it can be specified as follows:

$$w(\mathrm{n}) = \pi^{-\frac{1}{4}} e^{-iwn} e^{-\frac{1}{2}n^2} \quad = \qquad (7)$$

w denotes the non-dimensional frequency, i refer to $\sqrt{-1\, p(\backslash)}$, by using the space and time \ = 0,1…N-1. The wavelet continuous transformation of the time series, takes the following form:

$$w_{k,f}(n) = \frac{1}{\sqrt{h}} w\left(\frac{n-k}{f}\right), k, f \in \mathbb{R}, f \neq 0 \quad = \qquad (8)$$

In equation 9, the k and f respectively indicate time and frequency. The continuous wavelet transformation allows the cross-wavelet analysis to interrelate two variables and is defined in the following equation:

$$\mathfrak{w}_p(k,f) = \int_{-\infty}^{+\infty} p(n) \frac{1}{\sqrt{f}} \left(\overline{\frac{n-k}{f}}\right) dn, \quad = \qquad (9)$$

In equation 10, the local variance is defined by wavelet power spectrum or shortly know as WPS. Although, there are many formulas in literature specify the approach of wavelet coherence, but generally the specification of WTC can be given in equation 11. Where S indicates the time and scale smoothing operators with $0 \leq R^2(k,f) \leq 0$.

$$WPS_p(k,f) = \left|W_p(k,f)\right|^2 \quad = \tag{10}$$

$$R^2(k,f) = \frac{\left|S\left(f^{-1}W_{pj}(k,f)\right)\right|^2}{S\left(f^{-1}\left|W_p(k,f)\right|^2\right)S\left(f^{-1}\left|W_j(k,f)\right|^2\right)} \quad = \tag{11}$$

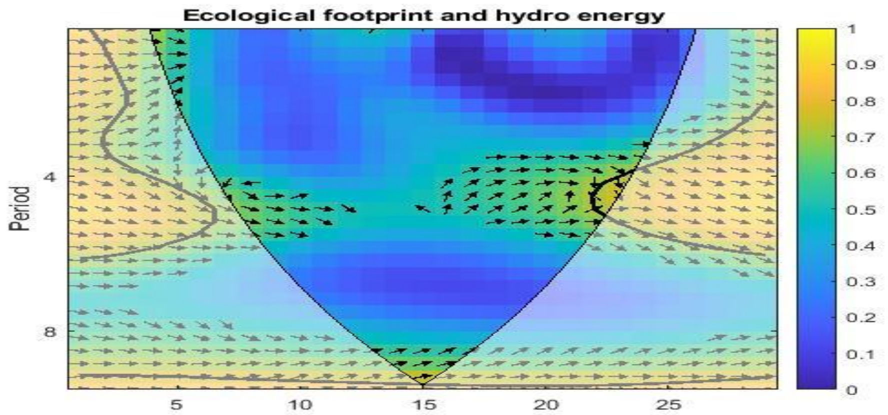
Figure **4(A to I)** presents the WTC among the variables of interest between 1990 and 2018, the full names are given within the relevant figures arranged based on the study objectives. The horizontal and vertical axis in each figure indicates the time and frequency respectively. The yellow and blue colors denote high and low dependence between the variables. The rightward and leftward arrows correspondingly show the in-phase and out-of-phase interrelations. Furthermore, the rightward-down or leftward-up indicates that the first series cause the second one. Whereas rightward-up (leftward-down) indicates that the second variable cause the first one. As the study's main objective, the first three figure (A, B, C) show the time frequency dependence between environmental sustainability and renewables.

At various frequencies, **Panel A** relatively show low dependence between ecological footprint and hydro energy, and most of arrows are leftward-down indicating negative interconnection between the two variables, this also means that hydro energy leads the ecological footprint. The same is true in **panel B** which presents the WTC between the ecological footprint and wind-solar energy, but the figure indicate high frequency dependence between the two variables with wind-solar energy leading. **Panel C,** however, indicates high and positive frequency dependence since majority of arrows are rightward-up. We can conclude that the first two figures are consistent with the VECM findings, but panel C contradicts the VECM result.

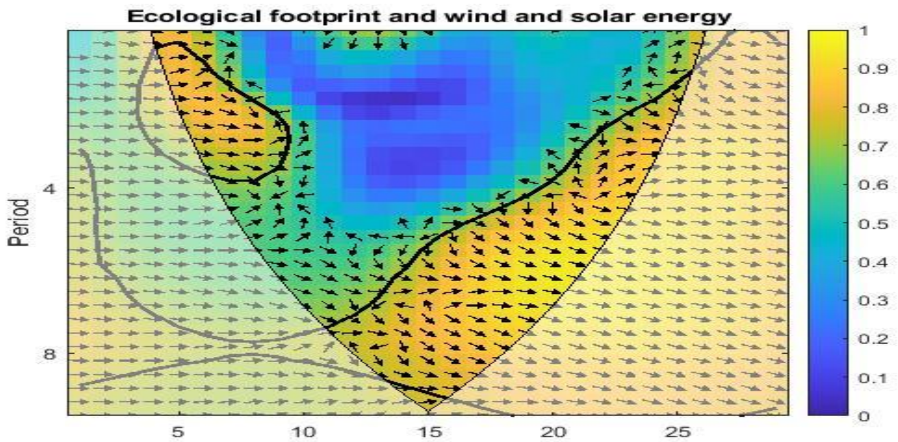
As the second most important objective of the study, **panel D**, exhibits the time-frequency dependence between environmental quality and globalization. Unsurprisingly, the figure shows high time frequency dependency between the two variables. The most of arrows are rightward-down indicating positive interrelation with ecological footprint leading. This is already expected and consistent with the VECM outcome. As the third objective, the rest of the figures present the time frequency dependence between economic growth and the other variables in our VAR system. The general trend of the international debate regarding the relationship between economic growth and environment, although there is no complete consensus, however, to some extent there is an agreement that is in long run the GDP can be a solution to the environmental degradation, as nations become rich, they tend to care of and preserve the environment. This view is supported by many empirical findings within the framework of environmental economic theories such Environmental Kuznets Curve and Pollution Haven hypotheses. Regarding the globalization and economic growth and renewable energy, the general plausibility is that as every country tries to attain the highest level of growth through international trade and industrialization, this required high volume of energy usage, which eventually may have an adverse effect on the environmental quality.

Figure 4(A-I): WTC Between The Study Variables

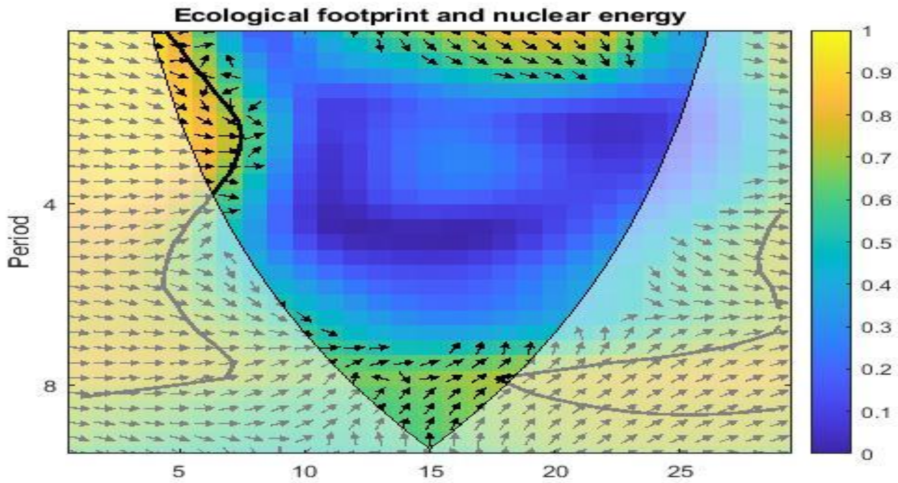
(A)



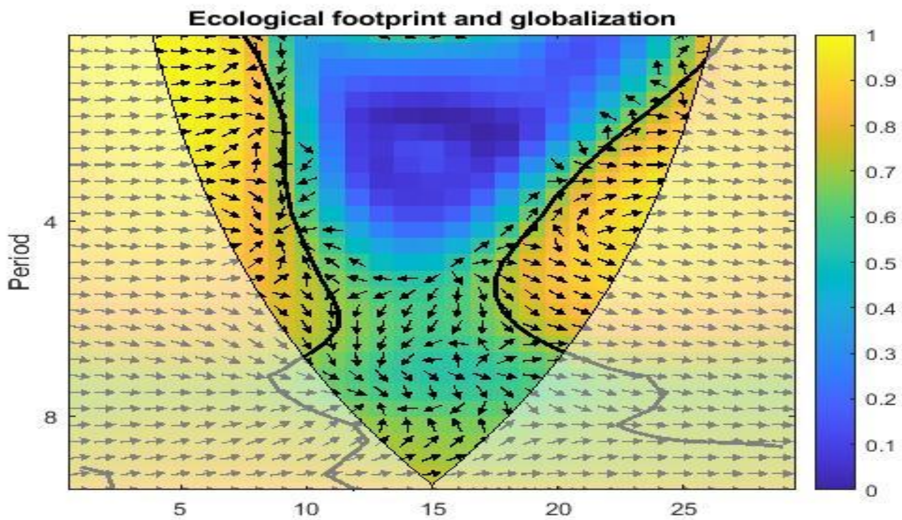
(B)



(C)

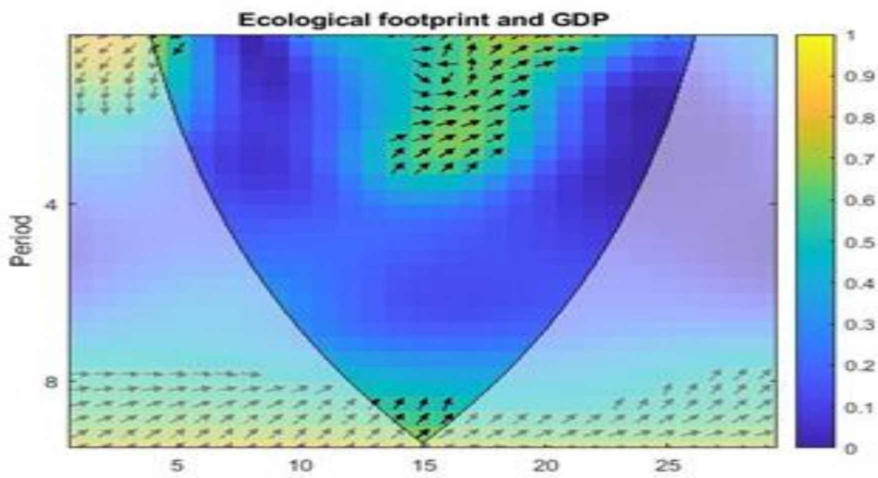

Ecological footprint and nuclear energy
Period
4
8
5
10
15
20
25
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

(D)

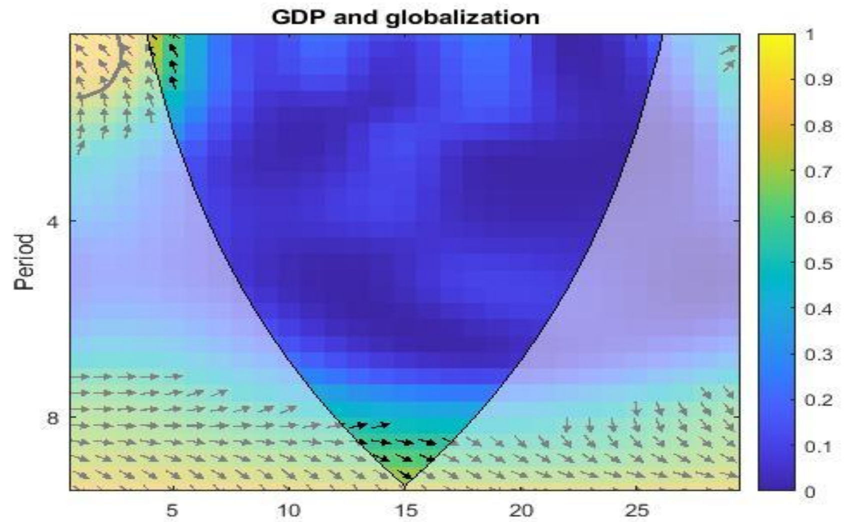

Ecological footprint and globalization
Period
4
8
5
10
15
20
25
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

Panel E although shows low frequency dependence at various scales, but the arrows are rightward-up indicating that economic growth contribute positively to pollution in India. The same is true also for the WTC between GDP and globalization in **panel F**, but the arrows are rightward-down indicating the globalization leads economic growth positively. This outcome specifically, agrees with our basic assumption. **Panel G, H** and **I** show the time frequency dependence between GDP and renewables. In energy economic literature, it is widely believed that the clean and reusable energy on one hand mitigate the environmental damages and on the other hand promote the economic growth. Although the empirical studies are far away to reach this agreement, but as the negative externalities of nonrenewable energy consumption have become more sever causing huge negative consequences on the environment, nation have started to seek for an alternative energy source in a way that keep the economic growth persistent. Our time frequency dependence in panels (G, H, I) show almost no dependence with an exception to the hydro energy which shows very low dependence with hydro energy leading. These results provide clear evidence against the theoretical perspectives. This may also indicate that renewable energy is represents only small size of total energy structure in economic sectors in India.

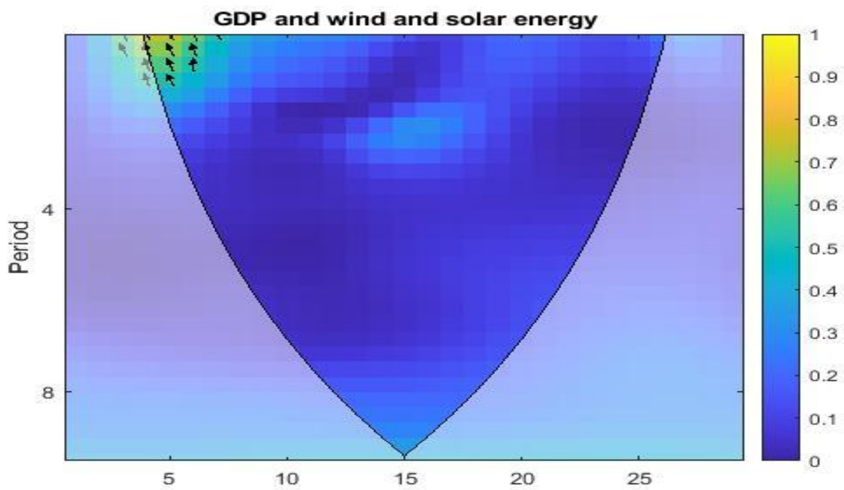
(E)



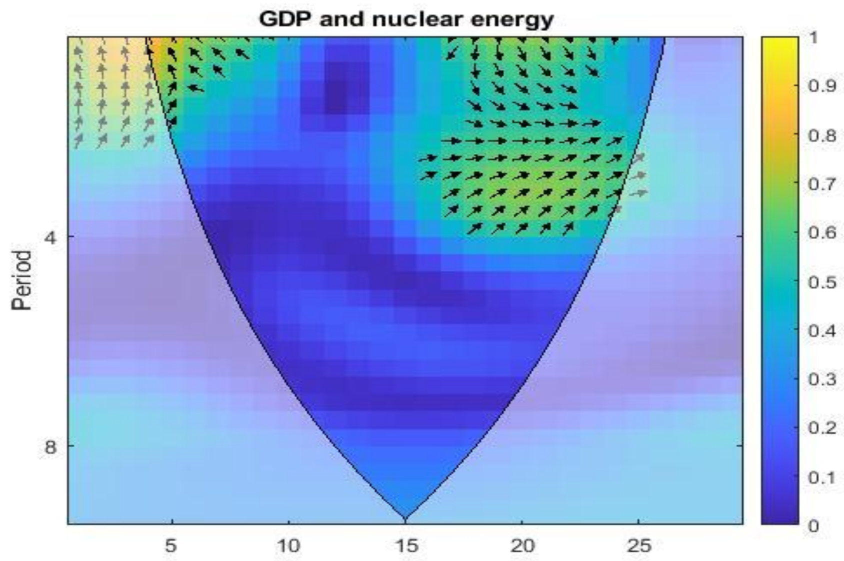
(F)


GDP and globalization
Period
4
8
5
10
15
20
25
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

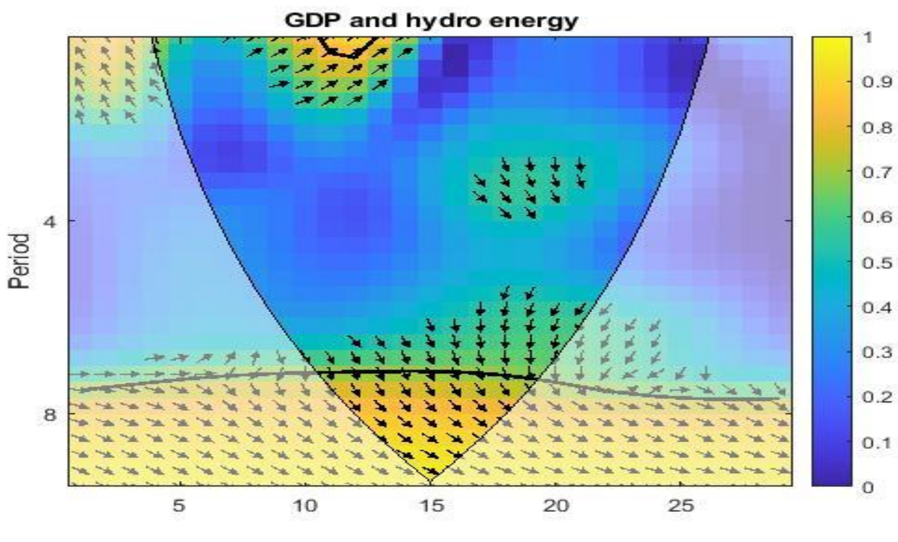
(G)


GDP and wind and solar energy
Period
4
8
5
10
15
20
25
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

(H)


GDP and nuclear energy
Period
4
8
5
10
15
20
25
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

(I)


GDP and hydro energy
Period
4
8
5
10
15
20
25
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

This study also performs some diagnostic and stability tests to make sure that the model is free from some measurement's errors. But firstly, we setoff regression specification error test basically, the Ramsey-reset test. Table 8 clearly show that our VECM model is free from any specification error since the null hypothesis of no regression specification error cannot be rejected. But since the test may just show statistical investigation outcomes, we firstly specified the regression taking into consideration the relevant theories from international economics, energy, and environmental economic literature. Table 9 and 10 present diagnostic tests mainly the Breusch-Godfrey Serial Correlation LM Test and heteroskedasticity test: Breusch-Pagan-Godfrey. Both tests confirm that our model is free from serial correlation and heteroskedasticity problems since we cannot reject null hypotheses of no dianostic problems. In addition, the stability of models is assessed using the CUSUM and CUSUMSQ tests. Figures 5 and 6 present the findings of CUSUM and CUSUMSQ. The model has passed the CUSUM test indicating the stability of the estimated parameters. However, the CUSUMSQ test indicates that there is a slight deviation from 5 percent boundaries.

Table 8: Ramsey RESET Test

Specification: LOG(EFP) LOG(GDP) LOG(GLB) LOG(HYD) LOG(NUC) LOG(WSO) C			
Omitted Variables: Squares of fitted values			
	Value	df	Probability
t-statistic	0.701226	22	0.4905
F-statistic	0.491718	(1, 22)	0.4905
Likelihood ratio	0.641037	1	0.4233
F-test summary:			
	Sum of Sq.	df	Mean Squares
Test SSR	0.000461	1	0.000461
Restricted SSR	0.021073	23	0.000916
Unrestricted SSR	0.020613	22	0.000937

Table 9: Breusch-Godfrey Serial Correlation LM Test:

F-statistic	**3.017733**	**Prob. F(2,21)**	**0.0705**
Obs*R-squared	6.474033	Prob. Chi-Square(2)	0.0393

Table 10: Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	**1.469628**	**Prob. F(5,23)**	**0.2381**
Obs*R-squared	7.021718	Prob. Chi-Square(5)	0.2190
Scaled explained SS	4.694677	Prob. Chi-Square(5)	0.4543

Figure 5: CUSUM Stability Test

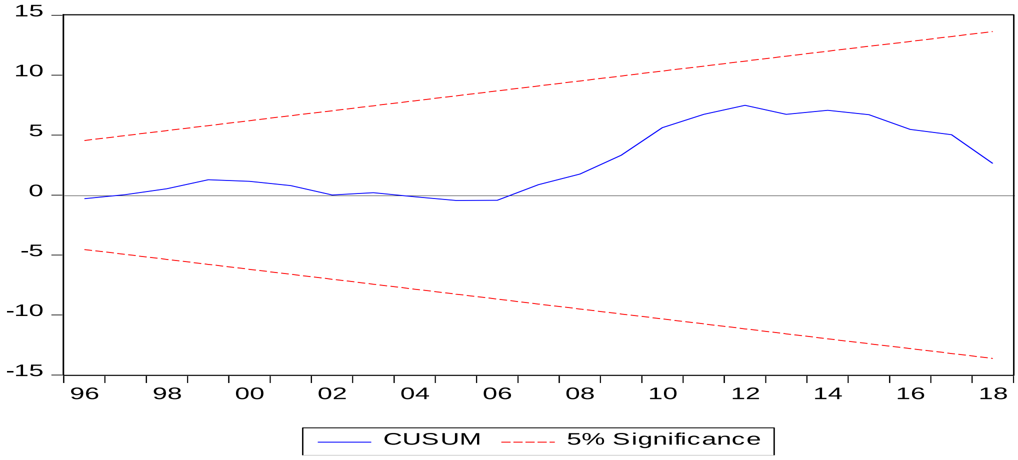
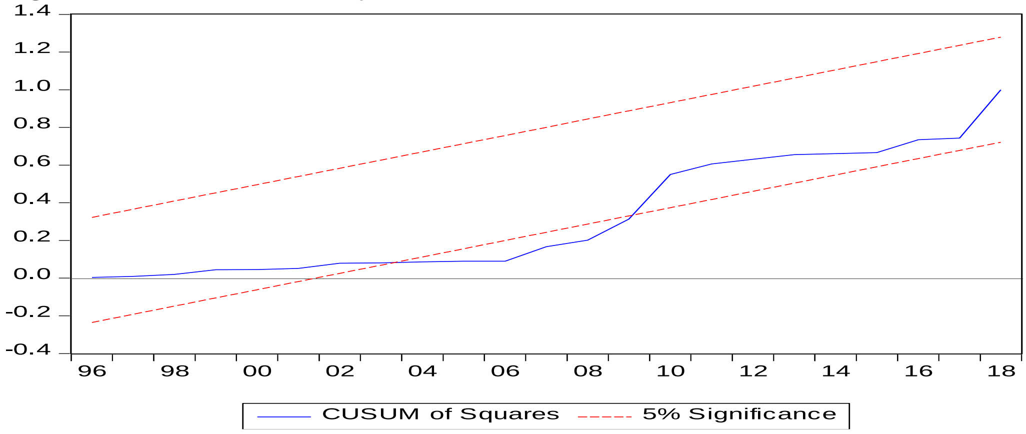


Figure 6: CUSUMSQ Stability Test



CONCLUSION AND POLICY IMPLICATIONS

In the regrads of vibrant developemnt of renewable energy sources, and the increase in integration of the world economies, this research tired to contribute to the global discussion of the possible dynamic effect of globalisation and renewable energy on enviroenmental quality with the emphasis on the Indian economy and environment.

The study employed VECM due to many avantages comparing to other multivariate models. The study utilzied annual dataset covers the period 1990 to 2018 selected based on the data availbility. Moreover, to have a btter understanding to the movement and dynamics over time this study employed Morlet wavelt transformation (WTC) to detect the time frequency dependency among the underlying variables.

Eliminating the preliminary investigation results, the VECM discloses considerable results, most of them are consistent with theoretical perspectives and not much less than empirical findings. Basically, the GDP and globalization are positively contributing to the environmental deterioration in India. The renewable and clean energy (hydro, nuclear, wind and solar) are found to be environmentally friendly and helpful in mitigating the environmental damage. With a little exception, the WTC analysis disclose almost similar result to VECM model despite their different purposes, the interconnection overtime shows high similarities. However, in this vein the puzzling result is the low or almost no dependency between renewables and economic growth in terms of GDP. This result might be due to low share of renewables in total energy combination, which is highly supported by energy data provided in the preface section. Based on the obtained findings, it is extremely important to draw some recommendations.

Firstly, although, the tremendous development in the clean and renewable energy in India cannot be overlooked however, there still more challenges. India is among the 20 largest economies in the world and by the same time India is among the first three most pollutant countries in terms of carbon emissions, therefore, it is vital to increase the share of clean and renewable energy not only to preserving the environment and keeping the growth of Indian economy persistent, but also to contributing to the global efforts in tackling the issues of global warming and climate changes. This can be done by creating more competitive environment for investment in the renewable energy market and this study provides the magnitudes by which this objective can be achieved.

Second, since the economies of the world are becoming more integrated, and to have more better understanding to the implication of renewable energy-environmental sustainability nexus, the future research should investigate these issues on the regions bases or groups of countries by following the panel data analysis such panel SVAR and panel VECM or even panel ARDL. This suggestion may provide more clear understanding to the impact of renewables' shocks in one country to the environmental quality in other countries. This might help the policy makers to draw more effective policies to mitigating environmental problems based on the integration among the countries.

Data share: the full dataset and EView and Matlab relevant work-files are shared in public data repository with *DOI: 10.6084/m9.figshare.15467517 and the link https://figshare.com/s/7c499019fe151b6947e1*

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