The Renewable Energy Consumption-Environmental Degradation Nexus in Top-10 Polluted Countries: Fresh Insights from Quantile-on-Quantile Regression Approach

Sharif, Arshian and Mishra, Shekhar and Sinha, Avik and Jiao, Zhilun and Shahbaz, Muhammad and Afshan, Sahar

University Utara Malaysia, C.V. Raman College of Engineering, Goa Institute of Management, Nankai University, Beijing Institute of Technology

15 December 2019

The Renewable Energy Consumption-Environmental Degradation Nexus in Top-10 Polluted Countries: Fresh Insights from Quantile-on-Quantile Regression Approach

Arshian Sharif
Othman Yeop Abdullah Graduate School of Business
University Utara Malaysia
Sintok, Kedah, Malaysia
Email: arshian.aslam@gmail.com

Shekhar Mishra
Department of Business Management
C.V. Raman College of Engineering
Bhubaneswar, Odisha, India
Email: shekhar.ximb@gmail.com

Avik Sinha
Department of General Management and Economics
Goa Institute of Management, India.
Email: f11aviks@iimidr.ac.in

Zhilun Jiao
College of Economic and Social Development
Nankai University, Tianjin, China.
Email: zjiao@nankai.edu.cn

Muhammad Shahbaz[1]
Center for Energy and Environmental Policy Research, Beijing Institute of Technology, Beijing 100081, China
School of Management and Economics, Beijing Institute of Technology, Beijing 100081, China
COMSATS University Islamabad, Lahore Campus, Pakistan
Email: Muhammad@bit.edu.ch, muhdshahbaz77@gmail.com

Sahar Afshan
School of Economics, Finance & Banking
College of Business
Universiti Utara Malaysia
Email: sahar_khan09@hotmail.com

Abstract: This empirical examination explored the link between renewable energy utilization and environmental degradation in top-10 polluted countries by using monthly data from 1990-2017. The Quantile-on-Quantile regression (QQ) proposed by Sim and Zhou (2015) and Granger causality in quantiles developed by Troster (2018) are applied. In particular, we examine in what manners, quantiles of renewable energy consumption affect the quantiles of environmental degradation. Our empirical findings unfold overall dependence between renewable energy consumption and ecological deterioration. The findings recommend the presence of a significant negative association between renewable energy consumption and environmental degradation in China, USA, Japan, Canada, Brazil, South Korea and Germany,

[1] Corresponding Author

predominantly in high and low tails but results are totally contrasting in the case of India, Russia and Indonesia. Furthermore, the outcomes of Granger-causality in quantiles conclude a bidirectional causal link between renewable energy consumption and environmental degradation. The empirical findings suggest that governments should need to subsidize green energy in declining ecological degradation.

Keywords: Renewable Energy; CO_2 Emissions; Quantile-on-Quantile (QQ) Approach; Granger-Causality in Quantiles.

I. Introduction

With the graduation of time, continuous consumption of fossil fuels is turning out to be one of the most grievous problems across the globe. Since a stint period of time, fossil fuel has been the major driving force behind global economic growth, but in recent times, the negative consequences of this action are becoming more predominantly visible, in the form of ambient air pollution (Sinha 2016, Sinha and Shahbaz 2018). Combustion of fossil fuel generates several forms of ambient air pollutants, which have several negative consequences on the sustainability of overall development process of any nation, as well as, the carrying capacity of earth. Over the years, nations have identified these predicaments, and as a result, the pursuit for alternate energy sources has started (Balcilar et al. 2018, Solarin et al. 2018, Shahbaz and Sinha 2019). In this regard, the scientists and policymakers have discovered renewable or green energy to be a solution to combat not only environmental issues, but also the issues of energy security arising out of higher demand of energy.

Taking a cue from this discussion, it can be well understood that energy policy measures being taken by the countries can vary depending on (a) the status of economic growth and development, (b) the characteristics of energy mix, (c) the status of technological advancement, and (d) the level of ambient pollution. Now, let us discuss these four conditions. First, for a nation with steady economic growth and sound developmental practices in place, it can be expected that energy policies will be ideally targeted at reducing reliance on fossil fuels consumption, increasing the research and development budget for discovery of alternate energy sources, and enhancing energy security (Sinha et al. 2018). Second, in order to lessen the ambient air pollution, policymakers strive to reduce the proportion of fossil fuels in energy-mix and increase the proportion of green power sources. In doing so, they try to encourage technological advancements, which is the third condition. When a nation tries to encourage research & development for discovering alternate energy resources, the advancements in technological domains are necessitated. This necessity can be fulfilled either by endogenous capacity building, or by exogenous technology transfer via international trade (Sinha et al. 2017). Therefore, the policymakers of these nations will be more prone towards trade liberalization and putting forth more investments in research & development. However, the fourth condition can be a premise for explaining sustainable development goals (SDGs), with a special focus on environmental concerns, while encompassing the previous three conditions. When the energy policies are targeted at handing environmental degradation, then primarily three SDGs could be achieved, i.e. reasonably priced and eco-friendly energy, adequate practices and output progression and environmental accomplishment (UNDP, 2017). Focusing on environmental degradation might encompass these broad SDG objectives, as more investment on renewable or green energy initiatives will help in reducing emissions, create employment opportunities, and as a whole, can add to economic growth, while uplifting the standard of life. Now, while addressing the issues of environmental degradation, broad areas of development must be addressed, without having compromising on economic growth front. In doing so, the policymakers might have to bring forth a transformation in the existing energy mix, and to bring forth technological innovation, they might require technology transfer via international trade (Shahbaz et al. 2017a, b, 2019, Liddle 2018). Keeping these into perspective, it is necessitated to scrutinize the role of renewable energy in the countries, which are characterized by high pollution.

Given the objectives of SDGs, it can be assumed that the nations are thriving to implement the renewable energy solutions to have a control over the environmental degradation being caused by the growth trajectory being attained by them. Therefore, it can be expected that energy policies of nations should also be aligned with the objective of betterment of environmental quality and assuring sustainable development. However, the penetration of renewable energy solutions has not been sufficient enough to encounter the environmental degradation issues. The policy level preference of the policymakers towards the elevation of economic growth might be one of the possible reasons to hinder the diffusion of renewable and green energy technologies across the nation. This economic growth might prove to be short run in nature, if environmental quality is not sustained by policymakers. It might be possible that this policy-level myopia is a consequence of forgoing of short-run economic losses, which might have occurred due to the higher implementation cost of renewable and green energy technological solutions. In order to foster economic growth, the firms rely more on fossil fuel-based solutions, as it might help in controlling the cost of production, and thereby making the production competitive in the global market. This very approach of the industries might be supported by the policymakers to traverse along the high growth trajectory. However, this nature of economic growth is not sustainable, as the consequential environmental degradation created along the growth path possibly can harm the basis of economic growth itself, by deteriorating the hygienic state of labor force. In view of this, it seems necessary to assess the impact of renewable and green energy consumption on environmental degradation, so that the results of this association can give a possible picture of the existing energy policies being followed, and the corrective policy recommendation can be provided, if necessary.

Taking a cue from this discussion, we endeavor to inspect the effect of green power utilization on emission of carbon dioxide on the monthly frequency data of top-10 polluting countries between the time span of 1990-2017. The sample countries chosen are Russia, China, Germany, Japan, South Korea, Brazil, Indonesia, Canada, India, and the USA. On one hand, these countries are achieving high economic growth and are also the highest contributors to global CO_2 emissions. In 2017, these countries have achieved 61.43% of global GDP, whereas their contribution to global CO_2 emissions has been 65.61% (World Bank, 2018). This statistic show that economic growth trajectory attained by these countries have put more emphasis on economic growth itself, rather than sustaining the basis of growth. In pursuit of industrialization, retention and betterment of environmental quality has been given less priority by the policymakers of these nations. Hence, the ecological imbalance happened due to the unsustainable nature of industrialization has triggered the need of revisiting the existing energy policies of these countries and evaluate them from the viewpoint of green power utilization, but not at the expense of output development. The increased trend of carbon emanation has led the regulatory authorities to work towards articulating and implementation of energy policies that would motivate the utilization of renewable power sources consequently producing the desirable influence on carbon emanations. Therefore, we intend to analyze the impact of green power utilization on carbon emissions in these nations, so that we can get a clear picture regarding the status of sustainable economic growth. Though extensive literature on the nexus between renewable energy and carbon emissions are available, still certain research gaps persist, which need to be addressed from the perspective of redesigning the energy policies in the nations characterized by high ambient air pollution. Therefore, the current study adds value into to the prevailing literature in four ways: (i) the present investigation examined the connection between renewable power consumption and ecological deterioration in top-10 polluting economies. (ii) This study employs Quantile Cointegration approach against the traditional cointegration method to lend superior reliability to cointegration findings. (iii) We examine the effects of green energy utilization on degradation of environment by adopting the novel approach of Quantile-on-Quantile regression (QQ) that underlies the usefulness of identifying the due relationship among the variables across numerous quantile of distribution (iv) We further analyze the causality between the variables by adopting newly introduced approach of causality in quantiles conceptualized and suggested by Troster (2018). In our analysis, we discovered the adverse effects of renewable power utilization on carbon emanations. Moreover, we also recognized the feedback causal association between utilization of green energy and carbon emissions.

Remaining of the study is outlined as following: Section-II reviewed the related studies. Section-III explicates the methodological framework and Section-IV encompasses the data and empirical outcomes. Section-V chalks out the policy implications, and Section-VI presents a conclusion.

II. Review of Literature

Existing literature on energy and environmental economics has plenty of evidence on the effect of renewable power utilization on degradation of environment but provided mixed empirical results. These investigations have utilized the sample of both time series and panel data in analyzing several countries. The results obtained from these studies can be categorized under four hypotheses, namely (a) *Renewable energy-led-emissions hypothesis* (consumption of renewable energy leads to Carbon emanation) (b) *Emissions-led-renewable energy hypothesis* (Carbon emanation influences consumption of renewable energy) (c) *Feedback hypothesis* (Bi-directional causal association between consumption of renewable power and carbon emanations) and (d) *Neutrality hypothesis* (no causal link between renewable power utilization and carbon discharge). We will categorize the review of literature following these four hypotheses.

Let us start with the *Renewable energy-led-emissions hypothesis*. For instance, Farhani and Shahbaz (2014) investigated the association between CO_2 emissions, consumption of electricity generated from renewable and non-renewable sources, and output for 10 MENA economies. They found the unidirectional causality flowing from consumption of green energy to carbon discharge. Subsequently, Apergis and Payne (2015) while examining the causality between renewable power utilization, output, carbon emanation, and crude oil for 11 South American countries with Engle and Granger (1987) approach found similar results. In a subsequent study, Liu et al. (2017b) analyzed the association between the utilization of green and non-green energy, agricultural output, carbon emanation in BRICS. They employed VECM approach and observed uni-directional causal link from green energy utilization to carbon discharge. In Pakistan, Khan et al. (2018) while applying Toda Yamamoto Granger Causality approach to explore the connection between agriculture, production of electricity, green energy and GHG discharge, discovered that utilization of green energy influence carbon discharge.

Afterwards we proceed towards the *Emissions-led-Renewable energy hypothesis*. For instance, Menyah and Wolde-Rufael (2010) investigated Granger causality analysis to examine the linkage between consumption of green and nuclear energy, CO_2 emissions and real GDP. In their analysis, the authors found CO_2 emissions significantly influencing renewable energy consumption. Similarly, in Portugal, Leitão (2014) observed unidirectional causal link from carbon emanation to the utilization of renewable energy. Shafiei and Salim (2014) analyzed the determining factors of carbon discharge for OECD countries, and using panel VECM approach, they found unidirectional casual association flowing from carbon discharge to green energy utilization. In Tunisia, Jebli and Youssef (2015) explored the linkage between trade openness, green and non-green energy and output development under

EKC framework. They observed unidirectional causal link from carbon discharge to green energy utilization regardless of whether import or export-oriented variables are employed in the model. Paramati et al. (2017) performed a similar analysis for Next-11 countries by employing Dumitrescu-Hurlin (2012) panel causality test. The authors' findings also supported the Emission led Renewable Energy hypothesis.

Subsequent to this discussion, we will move towards the *Feedback hypothesis*. In this context, Apergis et al. (2010) investigated the linkage between output development, utilization of green and nuclear energy, and carbon discharge in 19 developed and developing countries by employing VECM approach. In their study, the authors observed the presence of bi-directional causal link between the utilization of green energy and carbon discharge. Dogan and Seker (2016) while investigating the linkage between consumption of green and non-green energy, carbon discharge, output development and trade liberalization with Dumitrescu-Hurlin (2012) heterogenous panel causality test found bi-directional causal link between carbon discharge and green energy consumptions. Assessing the association between carbon emanation, output development, natural gas and green energy utilization for BRICS economies, Dong et al. (2017) found the feedback effect between renewable energy utilization and carbon discharge. Similarly, Waheed et al. (2018) employed panel VECM approach to analyze the association between green energy utilization, agricultural and forest production, and carbon discharge in Pakistan. The authors in their estimations also reported the existence of feedback link between green energy utilization and CO_2 emissions.

Lastly, we will move towards *Neutrality hypothesis*. Bento and Moutinho (2016) analyzed the association between CO_2 discharge, real GDP, electricity generation from green and non-green sources, and global trade for Italy. Using Toda-Yamamoto procedure, they found no causality between CO_2 emissions and production of electricity from green sources. In a study on 25 OECD countries, Jebli et al. (2016) failed to the significant link between CO_2 emissions and consumption of green energy. While examining the linkage between output development, carbon discharge and utilization of nuclear and green energy from the data of nine developed countries, Saidi and Mbarek (2016) found neutrality between utilization of green energy and CO_2 discharge. Boontome et al. (2017) explored the link between nonrenewable and utilization of green energy, CO_2 emissions, and output development in Thailand using the empirical estimation of VECM framework. They found the neutral effect between green energy utilization and CO_2 discharge. Similarly, Jebli and Youssef (2017) while analyzing the link between green energy, produce from agriculture, carbon discharge, and output growth for 5 North African economies with Granger causality test failed to find the causal connection between CO_2 emanation and consumption of green energy. On employing VECM approach for four ASEAN countries, Liu et al. (2017a), established no causality between green energy and carbon discharge.

In continuation with the discussion, we should also mention the studies producing mixed results. Apergis and Payne (2014) analyzed the association between green energy, CO_2 discharge, growth and energy prices for 7 Central American economies, by means of panel Granger causality approach. Their empirical results were bifurcated in two parts, i.e. pre-2002 and post-2002 regimes. The authors found feedback effects between consumption of green energy and carbon discharge during pre-2002 regime. However, during post-2002 regime, uni-directional causal link from carbon discharge to consumption of green energy was observed. Sebri and Ben-Salha (2014) conducted a study for BRICS economies between 1971 to 2010, investigating connection between trade openness, economic growth, consumption of renewable power and carbon discharge. For Brazil, the authors found neutrality between utilization of green energy and carbon discharge. However, for India and South Africa, the authors found CO_2 emissions influencing renewable energy consumption. Zeb et al. (2014) explored the causal relationship between consumption of green energy, carbon discharge, poverty, depletion of natural resources and economic growth for five SAARC countries with the multivariate Granger causality approach. The authors found neutral effect between utilization of green energy and carbon discharge for Sri Lanka, Nepal, Pakistan, and Bangladesh, whereas for India, there existed unidirectional causal association running from the utilization of green energy to carbon discharge. Bélaïd and Youssef (2017) focused to examine the causality between carbon emanation, utilization of electricity generated from green and non-green sources, and output development of Algeria with Granger Causality approach. The researchers found unidirectional causal link from consumption of green energy to carbon discharge in short run, while the opposite in long run. Sinha et al. (2018) inspected the causality connection between output growth, utilization of green and non-green energy, and carbon discharge for Next-11 countries. Their empirical analysis also reported the mixed evidence on renewable energy consumption–carbon emissions nexus.

<Insert Table 1 here>

Existing literature provides us with no consensus regarding the direction of causality between consumption of renewable energy and CO_2 emissions. During the course of this review, we can see that the causal association not only vary with the context setting, but also with the methodological adaptations. Now, if we look at the contexts being chosen for carrying out these studies, then we can categorize the choices under three broad categories, namely (a) geographical boundaries, (b) eco-politically and geo-politically classified groups, and (c) the level of development. In this study, the countries are chosen based on the level of ambient air pollution in these countries, and for examining the association between renewable energy consumption and environmental degradation. Moreover, this study uses causality-in-quantiles, which is more robust compared to existing causality approaches (Jeong et al. 2012). Thus, contextually and methodologically, this study comprehensively adds value to the existing literature of energy and environmental economics.

III. An Overview of Energy Policies in the Selected Nations

Since 1949, China is working relentlessly towards adequate supply of energy to ensure sustainable economic growth (Andrews-Speed, 2014). In 2009, with a growth of 44% in carbon emissions since 2004, China became the highest producer of greenhouse gases around the globe (Shah 2006, Brahic 2007). However, it substantially reduced its CO_2 emissions per unit GDP by 20% between 2010 and 2015 (Tianjie 2016). In 2014, China ranked 42nd globally in terms of GHG emissions. As on date, China is the world leader in production of hydroelectricity, solar power and wind energy (Jha, 2008). They largely follow decentralized mode of policymaking for renewable energy, as the country's green energy industry is administered by several government bodies and corporate houses.

In United States, energy policy addressing the issues pertaining to production, distribution and consumption is largely governed by government and municipal entities. The different states devise enticement-based energy-efficiency schemes, which have an important part in country's energy policy in general. In 2016, out of total primary energy consumption of United States, energy from renewable sources accounted for 12.2% (EIA, 2018). After China, Canada and Brazil, United States ranked fourth among the largest hydroelectricity producers in the world. It possesses some of the best renewable energy resources, which can significantly cater to nation's rising demand of energy. In India, the country's rising energy deficit drives its energy policy with the increased emphasis on harnessing alternate energy sources, especially nuclear, solar and wind energy. With 66% of overall self-sufficiency in energy, India ranked 81 in year 2014 (EIA 2016, 2019). With 5.6% of global share, India was third largest consumer of primary energy after China and U.S.A in year 2017 (BP, 2018). Owing to its rising energy demands being unable to be met by existing oil and gas reserves, India is relentlessly working upon expansion of renewable energy program. India is the fourth largest wind power market intending to add about 100,000 MW of solar power capacity by 2020 (GWEC, 2018). In year 2016, India ranked second behind China in production of renewable energy with 208.7 Mtoe (IEA, 2019). In electricity sector, the contribution of renewable energy is 34.4% of total installed power capacity.

The key priorities of energy strategy of Russia are increased energy efficiency, reduced impact on environment, sustainable development, development of energy and technology, which would ultimately lead to improved effectiveness and competitiveness. Owing to the absence of conducive government policy framework and ambiguous policy signals, renewable energy in Russia is relatively underdeveloped. Moreover, its growth in the country has also been hindered by too much subsidies for natural gas, electricity and heating. In Japan, at present 10% of electricity needs is met from renewable sources. In the aftermath of 2011 disaster at Tokyo Electric Power Co.'s Fukushima Nuclear power plant the Japanese regulatory authorities were compelled to revisit, introspect and rework on their energy plan. The country's fourth strategic energy plan intends to enhance the share of renewable energy to 24% by the year 2030. The Japanese government has rolled out its ambitious feed-in tariff scheme to encourage the production and purchase of renewable energy in Japan. Under this scheme, the companies are encouraged to make investment in renewable energy production by quoting set prices for varied types of renewable energy. The Japanese government has vowed to upsurge the share of renewable energy sources from 15% to 22-24% inclusive of wind and solar by 2030 to meet the climate change commitments pursuant to Paris agreement.

Germany earns the enviable distinction of being the World's first major renewable energy company. Renewable energy in Germany is primarily composed of wind, solar and biomass. By the end of 2017, the proportion of renewable electricity stood at 36.2% of consumption. The federal government in Germany is reorienting its policy towards increased commercialization of its renewable energy. Energiewende, the term designate for Germany's energy transition indicates its significant shift in energy policy since the year 2011. The policy points towards its reorientation from demand to supply and shift from centralized to distributed generation culminating in energy saving measures and enhanced efficiency. In South Korea, energy policy has set the ambitious plan of producing 6.1% of power from renewable sources at the end of year 2020. The policymakers also aim to double this portion at the end of 2030 (Shin, 2015). Moreover, the wind potential of South Korea stands at 186.5TWh per year and the tidal power can generate 552 Million kWh per year (Chanal and Meisen, 2012). The current strategy of South Korea also intends to make investment in international alternate energy market and work towards implementation of energy efficient building for arresting the increased energy wastage.

In Canada, renewable energy intensive technologies constitute about 17% of supply of total primary energy and has a share of 65% of total electricity production as of year 2016 (NRC, 2018). The country was the second largest producer of hydroelectric power and eighth largest producer of wind power in the year 2016. According to Statistics Canada, environmental and clean technology activities accounted for 3.1% of Canada's GDP in the year 2016. In the year 2015, the federal government and the provincial leaders arrived at a consensus to cooperate with each other for boosting nations' industrial sector while making a transition towards low carbon economy. They reached at an agreement, which aimed to promote energy efficiency, transition to low carbon economy and enhance awareness about need of energy efficiency in the provinces of Canada. As of year 2018, 79% of domestic production of electricity in Brazil came from renewable energy sources (Capital Invest, 2018). Apart from its heavy reliance on hydroelectricity, the Brazilian government is also intending expand the share of biomass and wind energy which at present stands at 6%. The Brazilian policy measures are encouraging renewable energy sectors through number of conducive schemes and acts like financial subsidies and renewable energy acts. The boost is renewable energy sectors is also catalyzing the industrial growth in the country. The Brazilian government is also encouraging increased participation by private sector in renewable power sector. Indonesia with over 40% of energy consumption ranks largest energy consumer in the ASEAN region. According to the estimates made by the 5th ASEAN energy this position of the country is expected to remain unchanged till 2040. The Indonesian policy makers are framing strategies to meet national renewable energy target of reaching 23% of renewable energy in the energy mix of the region by 2025. The country has already reached 12.7% of renewable energy share in their electricity mix.

<Insert Table 2 here>

IV. Methodology and Data

IV.I. Quantile-on-Quantile Regression Approach

The present paper investigates the linkage between consumption of renewable energy and carbon emissions for a given country under study with the novel approach of Quantile on Quantile Regression (QQ) approach introduced by Sim and Zhou (2015). The Quantile model examining the influence of quantile of renewable energy on the quantiles carbon emanation is inclusive of QQ approach. This novel approach is the amalgamation of non-parametric estimation and quantile regression. The conventional Quantile Regression model explores the effects of renewable energy on the different quantiles of carbon emanation. Apart from that, the typical Linear Regression model estimates the impact of particular quantile of independent variable on the dependent variable. The Quantile on Quantile Regression approach combines these two traditional approaches to framework the linkage between quantiles of renewable energy and carbon emanation. This helps in getting a clearer picture on the association between the variables under study as compare to other previously employed assessment methods i.e. Quantile Regression and Ordinary Least Squares model (OLS). In the present paper the QQ approach examines the impact of consumption of renewable energy on carbon emissions and vice versa. The QQ model based on the Non Parametric Quantile Regression model is framed as follows:

$$CE_t = \beta^{\theta}(RE_t) + u_t^{\theta} \quad (1)$$

$$RE_t = \beta^{\theta}(CE_t) + u_t^{\theta} \quad (2)$$

In the given equation-1 and 2, CE_t and RE_t explain carbon emissions and consumption of renewable energy respectively. θ represents the θth quantile of the conditional distribution growth of the criterion variable, and u_t^{θ} explains the quantile residual term with conditional θth quantile expected to have zero value. β^{θ} $(\cdot)$ is termed as an unidentified function because we do not have prior knowledge on relationship between the variables under study. The employed QQ model explains the influence of consumption of renewable energy on carbon emissions and vice versa for top ten carbon emitting countries of the world.

The selection of proper bandwidth owing to its crucial role in controlling the smoothness of the estimates is highly imperative in a non-parametric analysis. The increased bandwidth represents larger strength of bias whereas increased variance in estimation is indicated by smaller bandwidth. The proper selection of bandwidth is instrumental in striking a balance between bias and variance in the estimations. In the present research, based on the work of Sim & Zhou (2015) we select the bandwidth constraint h = 0.05.

IV.II. Granger-Causality in Quantiles Method

In the present research, we further apply a causality approach named Granger-causality in quantiles approach in order to examine causality in quintiles of green energy consumption and environmental degradation. According to Granger (1969), a factor Y_i does not Granger-cause to other factor X_i if previously Y_i does not support to predict X_i, as long as the prior X_i. Suppose that there is a explaining vector $\left(M_i = M_i^X, M_i^y\right)' \in \mathbb{R}^e, e = o + q$, where M_i^y is the previous outcomes of $Y_i M_i^y := \left(Y_{i-1}, \ldots, Y_{i-q}\right)' \in \mathbb{R}^q$. In this case, the current study established a null hypothesis from Y_i to X_i as given below:

$$H_o^{Y \nrightarrow X}: F_X\left(x \middle| M_i^X, M_i^y\right) = F_X\left(x \middle| M_i^X\right), \text{for all } x \in \mathbb{R}, \quad (3)$$

where $F_X(.\,|M_i^X, M_i^Y)$ is the provisional distribution function of X_i if (M_i^X, M_i^Y) based on the equation-3. Focusing Troster (2018), this research applies the D_T method by classifying the QAR method $m(\cdot)$ for complete $\pi \in \Gamma \subset [0,1]$. Moreover, the null of non-Granger causal association hypothesis is given below:

$$Q_\pi^X\left(X_i \middle| M_i^X, M_i^Y\right) = \lambda_1(\pi) + \lambda_2(\pi) X_{i-1} + \eta(\pi) Y_{i-1} + \mu_t \Omega_Y^{-1}(\pi) \quad (4)$$

here the parameter $\lambda_1(\pi), \lambda_2(\pi)$ and μ_t are evaluated by utmost probability in an equal number of different quantiles grid, and $\Omega_Y^{-1}(.)$ is the contrary of an outdated basic conditional distribution function. To correct the sign of causality between the factors, the current study evaluates the QAR method in equation-4 with lagged factor to one more factor. Lastly, the calculation of quantile autoregressive (1) framework by equation-4 is given below:

$$QAR(1): m^1 \left(M_i^X, \partial(\pi)\right) = \lambda_1(\pi) + \lambda_2(\pi) X_{i-1} + \mu_t \Omega_Y^{-1}(\pi), \tag{5}$$

IV.III. Data Collection

The yearly data set comprising of consumption of renewable energy and CO_2 emissions of top-10 polluting countries such as China, USA, India, Russia, Japan, Germany, South Korea, Canada, Brazil and Indonesia is sourced from Word Development Indicators (World Bank, 2018). This paper covers the period of 1990-2017. For empirical analysis, we convert annual data into monthly data by employing quadratic match-sum method. The quadratic match sum method eliminates the point to point point-to-point data variations (Cheng et al. 2012, Sbia et al. 2014, Shahbaz et al. 2017) for converting the low frequency data into high frequency data. In this way, the method is instrumental in making adjustments for the seasonal variations in the data. As compared to interpolation methods, the Quadratic Match Sum Method is more convenient and preferable to be adopted (Shahbaz et al. 2016, 2017, 2018). This method performs local quadratic interpolations by dividing the low frequency data by number of observations. The method fills in the observations of the higher frequency related with the period by employing the local quadratic polynomial for all the observations of the original yearly series. We form the quadratic polynomial by using sets of three end-to-end values from the actual data and fitting a quadratic into that. This ensures that total of interpolated monthly data value is equal to the given yearly data values.

< Insert Table 3 here>

<Insert Table 4 here>

The descriptive statistics for monthly data pertaining to renewable energy consumption and environmental degradation for sampled countries is reported in Table-3. Canada has the maximum consumption for renewable energy with the mean value of 1741.569 mt tons per capita followed by Brazil with mean value of 530.768 mt. tons per capita. The USA consumes renewable energy with the mean value of 451.133 mt. tons per capita. Among the Asian economies, renewable energy consumption by Indonesia is maximum with the mean value 326.606 mt. tons per capita followed by China and India with the mean value 259.131 mt. tons per capita and 218.225 mt. tons per capita respectively. The mean value of consumption of renewable energy by Japan and South Korea is 164.764 mt tons per capita and 51.433 mt tons per capita respectively. The European nations Russia and Germany consumes renewable energy to tune of mean value 169.928 metric tons per capita and 260.002 mt tons per capita respectively. The standard deviation values reveal that the maximum fluctuations in renewable energy consumption is observed in Germany (158.967) followed by USA (97.999).

While examining the data pertaining to carbon emissions, we find China emitting the maximum carbon emissions with the mean value 5762.493 per capita metric tons followed by USA (5349.822) and Russia (1689.947). Among Asian economies, the mean value of per capita emission of carbon emissions in India, Japan, South Korea and Indonesia is 1285.344, 1194.403, 455.050 and 343.683 respectively. Germany and Canada emit on an average 814.631 and 511.245 mt. tons per capita of carbon emissions respectively. The maximum volatility in emissions of carbon is observed in China with the standard deviation of 2892.577. The non-normal nature of the data pertaining to consumption of renewable energy and carbon emissions for the sample countries is confirmed by the statistically significant results of the Jarque Bera Test. The correlation between renewable energy consumption and carbon emissions for the top ten-10 polluting countries is shown in Table-4. From the correlation analysis, the highly negative correlation between consumption of renewable energy and carbon emissions is well evident for China, USA, Japan, Germany, South Korea, Canada and Brazil. For India, Russia and Indonesia, renewable energy consumption and carbon emissions are positively correlated.

V. Empirical Results and their Discussion

We employ Quantile unit root test to examine the stationarity of the data and report the empirical results in Table-5. The empirical results of Quantile unit root provide the values of persistence, t-stats and the critical values for the grid of 19 quantiles that are {0.05-0.95}. For avoiding the bottleneck pertaining to serial correlation, we further employ 10 lags of endogenous variable. The results of the quantile unit root test indicate the presence of unit root at level for the provisional distribution quantiles of the variables. However, the Quantile unit test confirms that the variables are stationary at first order difference. We explore the probability of cointegration between the variables by adopting the novel approach of Quantile cointegration test conceptualized and introduced by Xiao (2009). The cointegration model is applied alike in the equally spaced grid of 19 quantiles (0.05-0.95). Further in the given Quantile cointegration model we have employed two leads and lags of ($\Delta Z_{t,} \Delta Z_t^2$). The coefficient of the constancy check for quantile cointegration approach is presented in Table-6. The observed estimates indicate the existence of nonlinear long run relationship between renewable energy consumption and environmental degradation quantiles.

<Insert Table 5 here>
<Insert Table 6 here>

The empirical results of the Quantile on Quantile approach are illustrated in Figure-1. The estimates of the slope coefficient β_1 (θ, τ), capturing the effect of τ^{th} quantile of renewable energy consumption on θ^{th} quantile of carbon emissions and vice versa at diverse values of θ and τ for countries are presented in Figure-1. We find a considerable heterogeneity in the association between renewable energy and carbon emanations. The association between renewable energy and carbon emanations are observed to be considerably heterogeneous in nature.

For instance, in **China**, we observe negative yet weak influence of consumption of renewable energy on carbon emissions in the area combining the middle (0.5-0.6) quantiles and lower to higher quantiles. The positive effect is minimal and insignificant. In other areas adjoining the quantiles of renewable energy consumption and carbon emissions, the strength of negative effects of renewable energy consumption starts increasing and becomes strong in the areas covering the higher quantiles (0.8-0.9) of renewable energy consumption and lower to higher quantiles of carbon emissions. While analyzing the effect of carbon emissions on consumption of renewable energy, we observe strong positive effect of carbon emissions on renewable energy consumption in the area combining the middle quantiles. In other areas combining the quantiles of both the variables, we observe negative effect of carbon emissions, which becomes strong in the area adjoining higher quantiles of carbon emissions and lower to higher quantiles of renewable energy consumption. This segment of the results is in consonance with the findings of Chen et al. (2019). In **USA**, there exists a strong negative effect of increase in renewable energy consumption on carbon emissions in the area combing the lower to middle quantiles (0.1-0.5) of both the variables. In other areas, the negative effect of renewable energy consumption starts getting weaker and in the higher quantiles (0.6-0.9) of both the variables, the effect becomes insignificant. The influence of carbon emissions on consumption of renewable energy is positive at lower quantiles (0.3-0.4) of carbon dioxide emissions and lower to middle quantiles of renewable energy consumption. Again, at higher quantiles (0.8-0.9) of carbon emissions and lower to higher quantiles of renewable energy consumption strong positive effect is observed. This segment of the findings complements the findings of Sharif et al. (2019), by finding the variations in the impact of renewable energy consumption throughout the spectrum.

On contrary, in **India**, there exists a strong to very strong positive influence of consumption of renewable energy on carbon emissions across all the quantiles of the variables. In case of influence of carbon emissions on renewable energy consumption, although the impact is positive across all the quantiles, but the effect is not as stronger as observed in case of impact of consumption of renewable energy on carbon emissions. The renewable energy penetration in India is still at a nascent level, as the production processes in India are still mostly reliant on fossil fuel-based solutions. Moreover, the price of renewable energy solutions is also a major predicament in the way of implementation. Owing to this phenomenon, the positive ecological impact of renewable energy solutions is yet to be visible in case of India. This section of our outcomes opposes the finding of Sinha and Shahbaz (2018), who found the association to be negative. Similarly, in case of **Russia**, we observe a strong positive influence of renewable energy consumption on carbon emissions in the area connecting middle to higher (0.6-0.9) quantiles of renewable energy consumption and carbon emissions. In other areas adjoining the different quantiles of the variables under consideration, positive effect becomes weaker and there is an onset of negative effect. Carbon emissions is also having a strong positive effect on renewable energy consumption across middle to higher (0.6-0.8) quantiles of both the variables. However, in the area adjoining higher quantiles (0.8-0.9) of carbon emissions and lower to higher (0.1-0.9) quantiles of renewable energy consumption, there exists a strong negative effect of carbon emissions on renewable energy consumption. Similar to India, the production process in Russian manufacturing industry is still largely dependent on traditional fossil fuel-based solutions, and therefore, Russia is yet to experience the full potential of renewable energy solutions. Subsidization of traditional fossil fuel sources is also making renewable energy implementation a difficult task, and owing to this fact, the ecological effect of renewable energy consumption is negative, as it is largely coexisting with fossil fuel solutions. This particular segment of the results contradicts the finding of Dong et al. (2017). Similar to India and Russia, in **Indonesia** also, the consumption of renewable energy and carbon emissions complement each other and there exists a positive influence of both the variables on each other across all the quantiles with the strength varying from weaker to stronger. However, while analyzing the effect of carbon emissions, we observe its strong negative impact on renewable energy consumption in the area combining lower quantiles (0.1-0.3) of carbon emissions and higher quantiles (0.8-0.9) of renewable energy consumption. Dependence on traditional fossil fuel-based solutions is proving to be a major roadblock on the way of renewable energy implementation in Indonesia, and therefore, the processes with high-energy demand are using both renewable and non-renewable energy solutions together. Consequently, the high level of carbon emissions is found to be coexisting with high level of renewable energy consumption. This segment of the findings contradicts the results obtained by Shezan et al. (2018), who found renewable energy to be an environmental-friendly replacement for fossil fuel energy solutions.

In Japan we can very well observe the persistence of negative influence of consumption of renewable energy on emissions of carbon across all the quantiles. The negative effect is observed to be intense across the area combining lower (0.1-0.4) quantiles of the variables. The negative influence of carbon emissions on renewable energy consumption is detected to be strong in the area adjoining lower to middle (0.1-0.6) quantiles of carbon emissions and middle to higher (0.6-0.9) quantiles of renewable energy consumption. In other areas, we observe a weak positive effect. This segment of finding contradicts the finding of Zhang and Liu (2019), who found the association to be positive. Similarly, in **Germany,** we observe weak to strong negative effect of renewable energy consumption and carbon emissions on each other across majority of the quantiles. However, in the area adjoining higher quantiles (0.8-0.9) of both the variables, we observe a strong encouraging impact of carbon emissions on renewable energy consumption. Like the previous case, this segment of finding also contradicts the finding of Khoshnevis et al. (2018), where the authors found the association to be positive. Similar scenario also persists in **South Korea** where consumptions of renewable energy and emissions of carbon have negative effect on each other across majority of the quantiles. The presence of positive effect is insignificant. This segment of our findings complements the findings of the study by Lee and Choi (2018). In case of **Canada**, the effect of renewable energy consumption on carbon emissions is negative across all the quantiles whereas the effect of carbon emissions is positive across all the quantiles of renewable energy consumption. This segment of the results contradicts the finding of Sadorsky (2009), who found the said association to be positive. In **Brazil**, there exists a negative effect of renewable energy consumption on carbon emissions across all the quantiles of both the variables. However, the strength of negative effect ranges from weaker to stronger across the quantiles. When we analyze the influence of carbon emissions on renewable energy consumption, we observe its positive effect in the area adjoining middle (0.5-0.6) quantiles of carbon emissions and lower to higher quantiles of renewable energy consumption. This section of our outcomes falls in the parallel with the finding of Rüstemoğlu and Andrés (2016), who found green energy to be a critical deciding factor for CO_2 emissions in Brazil.

<Insert Figure 1 here>

We further examine the validity of QQ approach by comparing the evaluated quantile regression coefficient with τ-mean QQ coefficients. In Figure-2, the quantile regression plots and the average of QQ coefficients of the slope coefficients measuring the influence of consumption of renewable energy and emissions of carbon are illustrated. While analyzing the influence of consumption of renewable energy on carbon emissions and vice versa, in Figure-2 we can observe that the average of QQ estimates of the slope coefficient are alike to majority of the countries, irrespective of considered quantile. In some of the countries like India, Japan, Germany and South Korea the trend in QQR line and QR line are alike, but the values are somewhat dissimilar. The graphical evidence postulates that the estimates from the quantile regression model can be recovered from the summary of detailed information available in QQ estimates. The negative effect of renewable energy consumption is well evident in majority of the countries leaving aside India, Russia and Indonesia where we observe its positive effects. However, in case of Russia and Indonesia at higher quantiles negative effects of consumption of renewable energy on carbon emissions can be observed. In case of impact of carbon emissions on renewable energy consumption, its negative effect can be observed in all the countries except India, Russia and Indonesia again. Here also in Russia and Indonesia, the effect of carbon emissions on consumption of renewable energy is negative at higher quantiles. The negative effect indicates higher level of carbon emissions leading to reduced renewable energy consumption.

<Insert Figure 2 here>

<Insert Table 7 here>

The results of the Granger-causality test in quantiles to ΔRE_t and ΔCO_{2t} is reported in Table-7. From Table-7, we can very well witness the robustness of estimates to diverse conditions of QAR framework specifying the null hypothesis pertaining to Granger non-causality. Leaving aside the median quantile, at other quantiles, the presence of Granger causality from ΔRE_t and ΔCO_{2t} and vice versa is well evident. The strong influence of changes in consumption of renewable energy and carbon emissions on each other at 1% level of statistical significance is very well advocated by the outcome obtained from Granger Causality test in Quantiles. The empirical results demonstrate the existence of bidirectional causality between consumption in renewable energy and carbon emissions in all high and low tails of quantile distribution for all countries. This confirms that renewable energy cause carbon emanation and in resulting, carbon emanation cause renewable energy in sampled countries. These empirical findings are similar with Dong et al. (2018), who found the bidirectional causal association between carbon emissions and renewable energy consumption for China, Indonesia and India[2]. However, Dong et al. (2018) were not able to find the changes in the causal association along the spectrum of carbon emissions. Therefore, results of our study address that gap in the empirical research on renewable energy-carbon emission nexus in China, Indonesia and India. Cai et al. (2018) found the unidirectional causality running from carbon emissions to consumption of renewable energy for the USA. On the contrary, Hossain (2012) found the unidirectional causal connection running from renewable energy to carbon emissions in Japanese economy. Similarly, Cai et al. (2018) also found neutral effect between renewable energy and carbon emanations in Canada. In case of South Korea, Zhang (2018) failed to observe any sort of causal association between consumption of renewable energy and carbon emissions. For Brazil, Bildirici (2018) found presence of unidirectional causality running from carbon emissions to consumption of renewable energy.

VI. Conclusion and Policy Recommendations

This study investigated the relationship between renewable energy consumption and carbon emissions in case of top-10 polluting countries using month frequency data for the period of 1990-2017. We apply the Quantile-on-Quantile (QQ) approach, which can assess how various quantiles of green renewable consumption can affect various quantiles of

[2] Shahbaz et al. (2013) and Hwang and Yoo (2014) have shown the existence of bidirectional causal association between energy consumption and carbon emissions, these studies were unable to disaggregate the impacts of renewable and non-renewable energy consumption on carbon emissions.

environmental degradation. It also allows us to give a more detailed explanation of the general dependence of renewable energy consumption on environmental degradation, compared to traditional approaches, such as OLS, ARDL, or quantile regression. We further apply the Granger-causality in quantiles introduced by Troster (2018) to examine the causal association among renewable energy consumption and environmental degradation.

The empirical outcomes report that renewable energy is negatively connected with environmental degradation for all countries, except India, Russia and Indonesia, while there are extensive variances throughout the countries and across all quantiles. The heterogeneity between the countries in renewable energy-environmental degradation nexus could be ascribed to several factors. First, the impact of green energy consumption can be impacted by technical and operational efficiency available. Furthermore, the nexus can also be affected by positive in some countries because of using non-renewable energy. Because of the high implementation cost of green energy implementation, it might not be possible for all the countries to bear a revenue deficit by hurting economic growth pattern. For those countries, dependence on non-renewable energy sources is more, and dissemination of the renewable energy solutions are carried out in small phases. Owing to this fact, the impact of green energy is not significant enough to reduce the level of carbon emissions, and therefore, the positive impact of renewable energy on carbon emissions can be visible, as cost of green energy implementation in one part of the country might be compensated by utilization of low-cost fossil fuel energy in other parts. Moreover, the heterogeneous effect of renewable energy consumption (environmental degradation) on environmental degradation (renewable energy consumption) in various countries requires that all countries be at identical stages of energy efficiency and economic development. For example, countries such as Germany, Japan, Canada, China, Korea and the US, present the most noticeable negative connection between renewable energy consumption and environmental degradation during periods of high economic growth. However, a noticeable positive relationship between renewable energy consumption and environmental degradation is found in India, Russia and Indonesia. This phenomenon might be attributed to the fact that renewable energy implementation scenario in these nations have not yet reached the maturity, and hence, energy demand in these nations is still catered mostly by non-renewable energy solutions. Moreover, owing to the cost of green energy implementation, policymakers of these nations are not been able to disseminate the nation-wide renewable energy implementation plans, as it might hurt the economic growth pattern by causing severe revenue deficit. By concentrating on the vigorous Granger-causality in quantiles method, empirical outcomes disclose the presence of feedback effect between renewable energy and environmental degradation in low, medium and high tails of distribution among all countries.

The prevailing energy policies in such countries can be visualized through the impact of green energy consumption on CO_2 emissions. Mostly the impact has been found to be either negative or gradually diminishing. However, the scenario has been found to be different for South Korea and Brazil. It shows that the penetration of green energy in these two nations has been proving out to be ineffective, as with the rise in green energy consumption, CO_2 emissions are found to be rising. Therefore, out of the 10 countries under consideration, these two countries fond to be more ecologically-unsustainable growth oriented. But when we looked into the impact of CO_2 emissions on green energy consumption, willingness towards the acceptance of green energy consumption became more prominent. Except India, Japan, and Germany, the demand of green energy has found to be either negative, or gradually falling. This lack of willingness towards embracing green energy solutions shows the tendency of policymakers to provide less priority towards environmental sustainability. In view of this, if we look at the bilateral association between green energy consumption and CO_2 emissions, no country has shown any evidence of environmental sustainability. For China, the USA, Russia, South Korea, Canada, Brazil, and Indonesia, willingness to accept the green energy solutions for reducing CO_2 emissions is either negative or gradually falling, and on other hand, South Korea and Brazil have shown the ineffectiveness of green energy consumption in reducing CO_2 emissions. The impact of green energy consumption is falling yet positive in case of India, and thereby demonstrating the inadequate diffusion of green energy solutions across the nation. In case of Japan, for the impact of green energy consumption on CO_2 emissions, the coefficients at higher quantiles of CO_2 emissions are found to be gradually rising (except the 95th quantile), and this issue is similar to that of the case of India. For Germany, willingness to accept the green energy solutions barely crossed the zero at the highest quantile of green energy consumption, and it also shows the tendency of policymakers to achieve economic growth at the cost of environmental quality. This discussion divulged the unsustainable vision of the existing energy and environmental policies in these nations, and therefore, the policy design needs to encompass all the countries under consideration in a unified manner, without tailoring them according to the individual contexts of the countries.

Implementation of renewable energy solutions in these nations can cater the solution to two major issues, i.e. energy efficiency and environmental degradation. In order to achieve energy efficiency, the policymakers should ponder upon diffusing renewable energy solutions in production processes, so that the dependence on traditional fossil fuel-based solutions can be reduced. The implementation of this process can be carried out via credit channeling mechanism, by providing differential interest rate mechanism. For the polluting firms, credit can be made available at higher interest rate, whereas the cleaner firms can avail the same credit at a cheaper rate. This burden of interest rate will compel manufacturing firms to implement renewable solutions in their production processes. While designing the credit channeling mechanism in this way, the policymakers also should discontinue the harmful subsidies on the traditional fossil fuel-based products, and thereby, discourage the people from using them. While carrying out these policy-level solutions, nations will be able to reduce revenue expenditures in terms of subsidies and can earn interest income from the credit channels. This growth in net revenue income might help them in implementing renewable energy solutions for poor households. Considering the retail or household consumers, this move might be imperative, as the price of renewable energy solutions might not be borne by them. As a result, a phased implementation of renewable energy solution for households should be undertaken. For example, during the initial phase, the high and medium income households can be provided with these solutions at a pro-rata rate from the local municipal bodies, from where these solutions will be available against less-expensive credit. The households might be given interest rate holidays based on their income level, and post that period, the interest income received from those households can be utilized for renewable energy implementation for poor households, which is the next phase of implementation. Following such a systematic implementation plan might help these nations to have a sustainable energy solution.

While saying this, it is also recommended that policy makers and regulators need to decrease their reliance on energy generated from fossil fuel-based sources, with a special focus on India, Russia and Indonesia. They should devise strategies, to encourage renewable energy consumption across all the sectors, as it would be instrumental in mitigating environmental degradation. However, policymakers should also consider not hurting economic growth pattern during the transition from nonrenewable energy to different sources of renewable energy. In this endeavor, the people-public-private partnerships should be encouraged, so that the perception about the benefits of renewable energy consumption and environmental protection can be increased among the citizens. This increase in awareness among the citizens might have multifaceted benefits, i.e. (a) public property rights can be defined in a better way, (b) the shift from fossil fuel to green energy consumption might start in an endogenous manner, (c) the industries will also start recognizing the need of green energy for organizational survival, and (d) new vocational opportunities might arise due to the implementation of green energy processes. It also has to be understood that in order to boost the green energy implementation process, the government in these countries need to generously fund development of alternative technologies to tap green energy resources like hydro-power, solar power, and wind power, while banking upon the existing human capital of nation. The researchers and universities should work towards production of cheaper energy from renewable sources, which is environmentally as well as economically sustainable. This will help the governments to devise conducive energy policies in these nations, which might help them in providing affordable and clean energy (i.e. SDG 7), encountering the problems of climatic shift (i.e. SDG 13), and ensuring decent work and economic growth (i.e. SDG 8). While addressing these three objectives of SDGs, these nations can have a big leap towards attaining the other objectives of SDGs, which will be founded on these three objectives.

References

Andrews-Speed, P., 2014. China's Energy Policymaking Processes and Their Consequences. Report no. 47, National Bureau of Asian Research.

Apergis, N., Payne, J.E., 2014. Renewable energy, output, CO_2 emissions, and fossil fuel prices in Central America: Evidence from a nonlinear panel smooth transition vector error correction model. Energy Economics, 42, 226-232.

Apergis, N., Payne, J.E., 2015. Renewable energy, output, carbon dioxide emissions, and oil prices: evidence from South America. Energy Sources, Part B: Economics, Planning, and Policy, 10(3), 281-287.

Apergis, N., Payne, J.E., Menyah, K., Wolde-Rufael, Y., 2010. On the causal dynamics between emissions, nuclear energy, renewable energy, and economic growth. Ecological Economics, 69 (11), 2255-2260.

Balcilar, M., Ozdemir, Z.A., Ozdemir, H., Shahbaz, M., 2018. The renewable energy consumption and growth in the G-7 countries: Evidence from historical decomposition method. Renewable Energy, 126, 594-604.

Bélaïd, F., Youssef, M., 2017. Environmental degradation, renewable and non-renewable electricity consumption, and economic growth: Assessing the evidence from Algeria. Energy Policy, 102, 277-287.

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, 142-155.

Bildirici, M., 2018. Impact of militarization and economic growth on biofuels consumption and CO2 emissions: The evidence from Brazil, China, and US. Environmental Progress & Sustainable Energy, 37(3), 1121-1131.

Boontome, P., Therdyothin, A., Chontanawat, J., 2017. Investigating the causal relationship between non-renewable and renewable energy consumption, CO_2 emissions and economic growth in Thailand. Energy Procedia, 138, 925-930.

Brahic, C., 2007. China's emissions may surpass the US in 2007. New Scientist. Available at: https://www.newscientist.com/article/dn11707-chinas-emissions-may-surpass-the-us-in-2007/

British Petroleum (BP), 2018. BP Statistical Review of World Energy.

Cai, Y., Sam, C.Y., Chang, T., 2018. Nexus between clean energy consumption, economic growth and CO_2 emissions. Journal of Cleaner Production, 182, 1001-1011.

Capital Invest, 2018. How to Invest in Brazil via Acquisitions: 2018-19 Brazilian M&A Guide. Available at: https://www.capitalinvest-group.com/en/invest-in-brazil-ma-guide/

Chanal, M., Meisen, P. 2012. How is 100% Renewable Energy Possible in South Korea by 2020? Global Energy Network Institute.

Chen, Y., Wang, Z., Zhong, Z., 2019. CO_2 emissions, economic growth, renewable and non-renewable energy production and foreign trade in China. Renewable energy, 131, 208-216.

Cheng, M., Chung, L., Tam, C.S., Yuen, R., Chan, S. and Yu, I.W., 2012. Tracking the Hong Kong economy. Occasional Paper, 3, 2012-2028.

Diks, C., Panchenko, V., 2006. A new statistic and practical guidelines for nonparametric Granger causality testing. Journal of Economic Dynamics and Control, 30(9-10), 1647-1669.

Dogan, E., Seker, F., 2016. Determinants of CO_2 emissions in the European Union: The role of renewable and non-renewable energy. Renewable Energy, 94, 429-439.

Dong, K., Sun, R., Hochman, G., 2017. Do natural gas and renewable energy consumption lead to less CO_2 emission? Empirical evidence from a panel of BRICS countries. Energy, 141, 1466-1478.

Dong, K., Sun, R., Jiang, H., Zeng, X., 2018. CO_2 emissions, economic growth, and the environmental Kuznets curve in China: What roles can nuclear energy and renewable energy play? Journal of Cleaner Production, 196, 51-63.

Dumitrescu, E.I., Hurlin, C., 2012. Testing for Granger non-causality in heterogeneous panels. Economic Modelling, 29(4), 1450-1460.

Energy Information Administration (EIA), 2016. Country Analysis Brief: India. Available at: https://www.eia.gov/beta/international/analysis_includes/countries_long/India/india.pdf

Energy Information Administration (EIA), 2018. U.S. Energy Facts Explained. Available at: https://www.eia.gov/energyexplained/?page=us_energy_home

Engle, R.F., Granger, C.W., 1987. Co-integration and error correction: representation, estimation, and testing. Econometrica, 55(2), 251-276.

Farhani, S., Shahbaz, M., 2014. What role of renewable and non-renewable electricity consumption and output is needed to initially mitigate CO_2 emissions in MENA region? Renewable and Sustainable Energy Reviews, 40, 80-90.

Geweke, J., 1982. Measurement of linear dependence and feedback between multiple time series. Journal of the American statistical association, 77(378), 304-313.

Global Wind Energy Council (GWEC), 2018. Global Wind Statistics 2017.

Granger, C.W., 1969. Investigating causal relations by econometric models and cross-spectral methods. *Econometrica: Journal of the Econometric Society,* 20(4), 424-438.

Hossain, S., 2012. An econometric analysis for CO_2 emissions, energy consumption, economic growth, foreign trade and urbanization of Japan. Low Carbon Economy, 3(3), 92-105.

Hwang, J.H., Yoo, S.H., 2014. Energy consumption, CO_2 emissions, and economic growth: evidence from Indonesia. Quality & Quantity, 48(1), 63-73.

International Energy Agency (IEA), 2019. Global Engagement: India. Available at: https://www.iea.org/countries/India/

Jebli, M.B., Youssef, S.B., 2015. The environmental Kuznets curve, economic growth, renewable and non-renewable energy, and trade in Tunisia. Renewable and Sustainable Energy Reviews, 47, 173-185.

Jebli, M.B., Youssef, S.B., 2017. The role of renewable energy and agriculture in reducing CO_2 emissions: Evidence for North Africa countries. Ecological indicators, 74, 295-301.

Jebli, M.B., Youssef, S.B., Ozturk, I., 2016. Testing environmental Kuznets curve hypothesis: The role of renewable and non-renewable energy consumption and trade in OECD countries. Ecological Indicators, 60, 824-831.

Jeong, K., Härdle, W.K., Song, S., 2012. A consistent nonparametric test for causality in quantile. Econometric Theory, 28(4), 861-887.

Jha, A., 2008. China 'leads the world' in renewable energy. The Guardian. Available at: https://www.theguardian.com/environment/2008/aug/01/renewableenergy.climatechange

Khan, M.T.I., Ali, Q., Ashfaq, M., 2018. The nexus between greenhouse gas emission, electricity production, renewable energy and agriculture in Pakistan. Renewable Energy, 118, 437-451.

Khoshnevis Yazdi, S., Shakouri, B., 2018. The renewable energy, CO_2 emissions, and economic growth: VAR model. Energy Sources, Part B: Economics, Planning, and Policy, 13(1), 53-59.

Koenker, R. and Bassett Jr, G., 1978. Regression quantiles. *Econometrica: journal of the Econometric Society*, 46(1), 33-50.

Lee, J.S., Choi, E.C., 2018. CO_2 leakage environmental damage cost–A CCS project in South Korea. Renewable and Sustainable Energy Reviews, 93, 753-758.

Leitão, N.C., 2014. Economic growth, carbon dioxide emissions, renewable energy and globalization. International Journal of Energy Economics and Policy, 4(3), 391-399.

Liddle, B., 2018. Consumption-based accounting and the trade-carbon emissions nexus. Energy Economics, 69, 71-78.

Liu, X., Zhang, S., Bae, J., 2017a. The impact of renewable energy and agriculture on carbon dioxide emissions: investigating the environmental Kuznets curve in four selected ASEAN countries. Journal of Cleaner Production, 164, 1239-1247.

Liu, X., Zhang, S., Bae, J., 2017b. The nexus of renewable energy-agriculture-environment in BRICS. Applied Energy, 204, 489-496.

Menyah, K., Wolde-Rufael, Y., 2010. CO_2 emissions, nuclear energy, renewable energy and economic growth in the US. Energy Policy, 38(6), 2911-2915.

Natural Resources Canada (NRC), 2018. Renewable energy facts. Government of Canada. Available at: https://www.nrcan.gc.ca/energy/facts/renewable-energy/20069

Paramati, S.R., Sinha, A., Dogan, E., 2017. The significance of renewable energy use for economic output and environmental protection: evidence from the Next 11 developing economies. Environmental Science and Pollution Research, 24(15), 13546-13560.

Rogers, S.A., 2012. What is green energy?. Mother Nature Network. Available at: https://www.mnn.com/earth-matters/energy/stories/what-is-green-energy

Rüstemoğlu, H., Andrés, A.R., 2016. Determinants of CO_2 emissions in Brazil and Russia between 1992 and 2011: A decomposition analysis. Environmental Science & Policy, 58, 95-106.

Sadorsky, P., 2009. Renewable energy consumption, CO_2 emissions and oil prices in the G7 countries. Energy Economics, 31(3), 456-462.

Saidi, K., Mbarek, M.B., 2016. Nuclear energy, renewable energy, CO_2 emissions, and economic growth for nine developed countries: Evidence from panel Granger causality tests. Progress in Nuclear Energy, 88, 364-374.

Sbia, R., Shahbaz, M. and Hamdi, H., 2014. A contribution of foreign direct investment, clean energy, trade openness, carbon emissions and economic growth to energy demand in UAE. *Economic Modelling*, *36*, 191-197.

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.

Shafiei, S., Salim, R.A., 2014. Non-renewable and renewable energy consumption and CO_2 emissions in OECD countries: A comparative analysis. Energy Policy, 66, 547-556.

Shah, S., 2006. China to pass US greenhouse gas levels by 2010. The Independent. Available at: https://www.independent.co.uk/news/world/asia/china-to-pass-us-greenhouse-gas-levels-by-2010-423407.html

Shahbaz, M., Hye, Q.M.A., Tiwari, A.K., Leitão, N.C., 2013. Economic growth, energy consumption, financial development, international trade and CO_2 emissions in Indonesia. Renewable and Sustainable Energy Reviews, 25, 109-121.

Shahbaz, M., Mahalik, M.K., Shah, S.H. and Sato, J.R., 2016. Time-varying analysis of CO2 emissions, energy consumption, and economic growth nexus: Statistical experience in next 11 countries. *Energy Policy*, *98*, 33-48.

Shahbaz, M., Bhattacharya, M., Ahmed, K., 2017a. CO_2 emissions in Australia: economic and non-economic drivers in the long-run. Applied Economics, 49(13), 1273-1286.

Shahbaz, M., Sinha, A., 2019. Environmental Kuznets curve for CO_2 emissions: a literature survey. Journal of Economic Studies, 46(1), 106-168.
Shahbaz, M., Solarin, S.A., Hammoudeh, S., Shahzad, S.J.H., 2017b. Bounds testing approach to analyzing the environment Kuznets curve hypothesis with structural beaks: The role of biomass energy consumption in the United States. Energy Economics, 68, 548-565.
Shahbaz, M., Taqvi, S.A., Loy, A.C.M., Inayat, A., Uddin, F., Bokhari, A., Naqvi, S.R., 2019. Artificial neural network approach for the steam gasification of palm oil waste using bottom ash and CaO. Renewable Energy, 132, 243-254.
Shahbaz, M., Van Hoang, T.H., Mahalik, M.K. and Roubaud, D., 2017. Energy consumption, financial development and economic growth in India: New evidence from a nonlinear and asymmetric analysis. *Energy Economics*, *63*, 199-212.
Shahbaz, M., Zakaria, M., Shahzad, S.J.H. and Mahalik, M.K., 2018. The energy consumption and economic growth nexus in top ten energy-consuming countries: Fresh evidence from using the quantile-on-quantile approach. *Energy Economics*, *71*, 282-301.
Sharif, A., Raza, S.A., Ozturk, I., Afshan, S., 2019. The dynamic relationship of renewable and nonrenewable energy consumption with carbon emission: A global study with the application of heterogeneous panel estimations. Renewable Energy, 133, 685-691.
Shezan, S.K.A., Al-Mamoon, A., Ping, H.W., 2018. Performance investigation of an advanced hybrid renewable energy system in Indonesia. Environmental Progress & Sustainable Energy, 37(4), 1424-1432.
Sim, N. and Zhou, H., 2015. Oil prices, US stock return, and the dependence between their quantiles. *Journal of Banking & Finance*, *55*, 1-8.
Sinha, A., 2016. Trilateral association between SO_2/NO_2 emission, inequality in energy intensity, and economic growth: A case of Indian cities. Atmospheric Pollution Research, 7(4), 647-658.
Sinha, A., Shahbaz, M., 2018. Estimation of Environmental Kuznets Curve for CO_2 emission: Role of renewable energy generation in India. Renewable Energy, 119, 703-711.
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, 1217-1229.
Sinha, A., Shahbaz, M., Sengupta, T., 2018. Renewable Energy Policies and Contradictions in Causality: A case of Next 11 Countries. Journal of Cleaner Production, 197, 73-84.
Solarin, S.A., Al-Mulali, U., Gan, G.G.G., Shahbaz, M., 2018. The impact of biomass energy consumption on pollution: evidence from 80 developed and developing countries. Environmental Science and Pollution Research, 1-17.
Tianjie, M., 2016. China's 5 Year Plan for Energy. The Diplomat. Available at: https://thediplomat.com/2016/08/chinas-5-year-plan-for-energy/
Troster, V., 2018. Testing for Granger-causality in quantiles. Econometric Reviews, 37(8), 850-866.
United Nations Development Programme (UNDP), 2017. Sustainable Development Goals. Available at: http://www.undp.org/content/undp/en/home/sustainable-development-goals.html
Waheed, R., Chang, D., Sarwar, S., Chen, W., 2018. Forest, agriculture, renewable energy, and CO_2 emission. Journal of Cleaner Production, 172, 4231-4238.
World Bank, 2018. World Bank Indicators. Retrieved from http://data.worldbank.org/indicator

Zeb, R., Salar, L., Awan, U., Zaman, K., Shahbaz, M., 2014. Causal links between renewable energy, environmental degradation and economic growth in selected SAARC countries: progress towards green economy. Renewable Energy, 71, 123-132.

Zhang, S., 2018. Is trade openness good for environment in South Korea? The role of non-fossil electricity consumption. Environmental Science and Pollution Research, 25(10), 9510-9522.

Zhang, S., Liu, X., 2019. The roles of international tourism and renewable energy in environment: New evidence from Asian countries. Renewable Energy, 139, 385-394.