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What drives renewable energy in the group of seven economies? Evidence from non-parametric panel methods

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ABSTRACT

In the last few decades, the environmental degradation, global warming, and climate change remained the life-threatening issues across the globe. Specifically, the use of non-renewable fossil fuels is regarded as the most significant reason of such inclined issues. However, the policy-makers and scholars are now more concerned about the recovery of environmental quality, where renewable energy is considered as the primary solution to the existing issue. The developed economies and environment related international organizations rapidly enhances the use and promotion of renewable energy after the taking pledge in the Kyoto Protocol Agreement (1997). Nonetheless, the scholars are participating in analyzing the key drivers of renewable energy. Still, the proper drivers of renewable energy are not properly addressed in the existing literature. To fill this gap, current study analyzed the group of seven (G7) economies over the period 1990-2020. Using various panel data techniques such as slope heterogeneity, cross-section dependence, unit root, and cointegration test, the results indicates that the slopes are heterogeneous, and the cross-section dependence, as well as cointegration exists among the panel economies. Besides, the irregular distribution of data leads to the adoption of novel Method of Moments Quantile Regression accommodating four quantiles, i.e., ($Q_{0.25}$, $Q_{0.50}$, $Q_{0.75}$, and $Q_{0.90}$). The examined results asserted that economic growth and energy efficiency negatively and significantly affects renewable energy consumption (*REC*). Whereas, developed environmental related technologies, environmental taxes, and composite risk index are positively affecting *REC* in the study panel. Besides, improved energy efficiency (energy efficiency squared) also contributed to the promotion of renewable energy consumption. The Granger causality test estimates reveals bidirectional and unidirectional causal association between the variables. Based on the empirical results, policies are provided that could help developed

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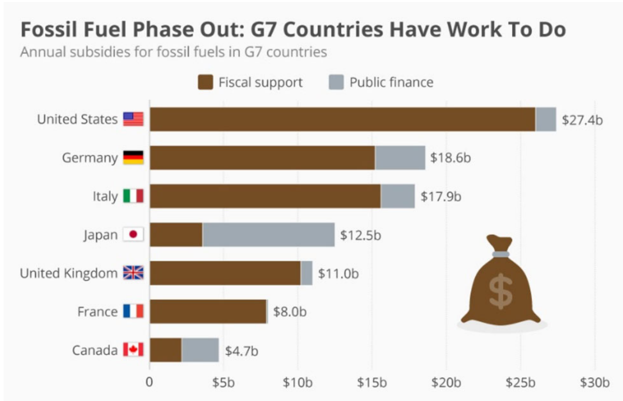
economies in the promotion of renewable energy consumption, improve economic growth, and enhances environmental sustainability.

1. Introduction

Energy, whether non-renewable or renewable is a critical factor of economic growth as it is a considered as the backbone of the industrial sector. As a result of rapidly growing population of the world, natural resources are exploited extensively to satisfy human needs for energy (Li et al., 2021). However, the extensive use of such natural resources and non-renewable energy resources undoubtedly leads environmental issues such as global warming, climate change, and environmental quality degradation. Besides, the higher energy demand in the industries as well as at the household level creates energy price volatility, which adversely affects economic growth and performance (Ma et al., 2021). On the other hand, renewable energy is created by replenishing natural resources in order to improve energy independence and address global warming, climate change and other environmental concerns. Since the energy demand is rapidly increasing across the globe: therefore, renewable energy could be used as a substitute for traditional non-renewable energy to help achieve sustainable development and economic growth in the long-run (Sebri & Ben-Salha, 2014). For instance, the US administration of energy information and international energy outlook report in 2016 demonstrates an expected increase of 48% in the global energy consumption by 2040. However, this immense increase in the energy consumption could further promote environmental issues. Therefore, policies targeting environmental quality improvement, renewable energy resources, pollution and emissions reduction are important for sustainable development. Therefore, this study tends to attract the scholarly attention towards this growing issue related to the hurdles faced in promoting renewable energy production and consumption. Although attempts have been made on the importance of renewable energy consumption on environmental quality (see Adedoyin et al., 2021; Baloch et al., 2019; Huang et al., 2021; Yuping et al., 2021). However, the issue that motivates this study is that the existing literature is limited in terms of demonstrating the appropriate factors that helps in the development of renewable energy. Which holds importance from both the environmental as well as economic growth perspective.

It is well known that the fossil fuels are produced only from the finite natural resources, that force authorities to debate on the balanced use of such resources. This is termed as the sustainable growth policy as it will not disturbs the available natural resources for the future generation. However, the imbalanced use of natural resources will significantly affect the capacity of natural resources to meet the needs of future generation. Despite the fact that several of the wealthiest nations have pledged to phase out fossil fuels, still they continue to spend roughly $100 billion each year on fossil fuel subsidies. A study released prior of the G7 conference in Canada shows the amount of money the G7 nations are paying to support gas, oil, and coal production and consumption. As per the Overseas Development Institute, the United States



Source: Statista (2018)[2]

Figure 1. Average carbon emissions in the G7 countries.
Source: Ibrahim and Ajide (2021)

subsidizes its fossil fuels to the extent of $27.4 billion per year. Despite significant progress in sustainable energy, Germany invests $18.6 billion on fossil fuels each year, slightly above Italy's $17.9 billion. As it is well known that increasing the production and consumption of fossil fuel consumption enhances the carbon emissions of region. For instance, the average carbon emissions in the G7 economies is reported in Figure 1, where the USA and Canada surpassess the average emissions level of the total G7 nations. Therefore, this issue of increased carbon emissions needs proper policy level attention to tackle the excessive use of fossil fuels while considering investment in renewable energy resources. Nonetheless, the initiatives targeting carbon neutrality could result in unemployment. Specifically, achieving carbon neutrality could lead to 300,000 jobs loss in the fossil fuel power plant sectors[1]. Therefore, its local effect requires substantial and continuous governmental attention to cushion communities as well as individuals. However, the recent report of IEA in 2021 claimed that transition towards clean energy generation and usage could help in the creation of 2.6 million jobs in the coming decade. Following this backdrop, current study tends to attract the attention of governors and policymakers toward this growing issue faced across the globe and particularly in the G7 economies. The details of fossil fuel subsidies for G7 economies details are given in Figure 2.

In order to achieve sustainable growth, countries across the globe are following renewable energy's path, which is a substitute conventional energy resources on the one hand, and promote environmental sustainability on the other hand. However, to promote environmentally friendly energy resources, there are various factors that influence renewable energy production and consumption. Such factors include economic growth, energy efficiency, environmental related technological innovation, and environmental related taxes, among others.[2] Although the literature concerning the nexus of such factors with the renewable energy is analyzed for various developed and developing economies. Still, the scholarly research on the such nexus is limited in various dimensions: firstly, the empirical evidence regarding the said nexuses is very limited as these scholars focuses a specific country. Secondly; there are

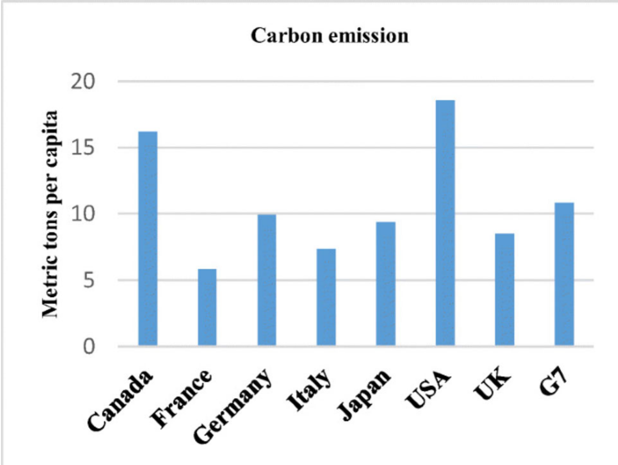


Figure 2. Fossil fuel subsidies in the G7 economies.
Source: Statista (2018)[3]

contradictions between the empirical evidence demonstrating both the positive as well as negative influence of different variables on the renewable energy. However, such policy level issue must be addressed properly to establish relevant and suitable policies for the adoption, production, and consumption of renewable energy. Based on the above discussion, this study observed that not only the contradictory evidence, but also the drivers or factors of renewable energy are unexplored yet – which is a substantial research gap. Hence, this study tends to address these issues and fill this gap via advanced and appropriate panel econometric approaches.

Following the research gap and limitation exist in the available literature, the purpose of this study is to empirically investigate the drivers of renewable energy consumption in the Group of Seven (G7) economies. Specifically, this study tends to examine the influence of economic growth on renewable energy. Nonetheless, the literature is rich concerning the influence of renewable energy on economic growth and development, yet limited in identifying the factors of renewable energy. Therefore, it is critical to discover that influence of relevant factors that could help in the development of renewable energy. Additionally, this study also aims to examine the influence of energy efficiency and energy efficiency improvement on renewable energy. The scholarly literature is very limited, even scant in describing the role of energy efficiency and improved energy efficiency on renewable energy. However, the role of energy efficiency in renewable energy cannot be ignored. Therefore, it is pertinent to empirically analyze the influence of these variables on renewable energy, particularly for developed nations as these economies are more concerned about their increased fossil fuel consumption. Moreover, the developed economies have taken various steps to reduce environmental quality degradation: therefore, these economies have imposed environmental taxes and invest in the environmental related technologies. These two measures are considered critical for environmental quality recovery and sustainable development. Hence, this study also objectivized to empirically analyze the influence of these two measures on renewable energy consumption. The final objective of this research is to analyze the association of composite risk index on renewable energy in the developed economies. The reason for selection these variables in the empirical investigation is that all these variables hold significant importance in the economic as well as the environmental related policy construction and implementation. The objectives mentioned above could be achieved via utilizing the novel method of moments quantile regression which is efficient in dealing the irregular data and provides empirical estimates at specific quantile for fixed time location and scale. The empirical results could help in the construction of policies that would help tackle the issue of excessive fossil fuel consumption and will promote the use of renewable energy in the region. Such policies could also be extended to other developed economies as the wealthier nations are more concerned about carbon neutrality target achievement.

Concerning the novelty and contributions of this research study, this is not an overstatement that the present research study is pioneering in answering the pertinent questions regarding the factors affecting renewable energy. Specifically, the G7 economies are struggling for improved environmental quality, where the authorities are worried about the improvement in renewable energy. Therefore, the empirical findings of this study will help the G7 economies to establish and implement relevant policies for renewable energy production and improvement. Apart from the G7 economies, other developed economies could also benefit from the estimated results of this research. Since the existing literature is scant regarding the drivers or factors affecting renewable energy consumption. Therefore, this study provides a pathway to the scholars to pay more attention on the determinants of renewable energy. Where this study could further be extended for emerging and developing economies. Unlike the previous studies, that utilizes tradition regression approaches for empirical testing, this study uses advanced econometric approaches, which are robust and more powerful in providing efficient estimates.

The rest of the paper is constituted into the following sections: Section 2 provides relevant review of literature; Section 3 demonstrates methodological setup used for empirical estimation; Section 4 reveals empirical results are discussion; while Section 5 represents conclusion and policy implications.

2. Literature review

2.1. Review of relevant literature for all variables

Since the debate regarding renewable energy and economic growth is a burning issue among researchers and policy-makers in the current times. Still, numerous efforts have been made by the scholars in provision of the empirical evidence regarding the association of renewable energy and economic growth. Specifically, the recent study of Mohsin et al. (2021) examined 25 Asian developing economies over the period 2000-2016 via employing random effect approach. The examined results reveal that economic growth and renewable energy are positively correlated. The study also claims that renewable energy is associated to the reduction of environmental pollution. Employing various empirical estimation methods, Li et al. (2021) and Anser et al. (2022) also demonstrates the positive influence of renewable energy sources (wind, biomass, hydro, and geothermal) on economic growth in the SAARC and

Asian economies during 1995-2018 and 1990-2018 periods, respectively. In the same line, Fu et al. (2021) validates the bidirectional causal association between renewable energy use and economic growth in the BRICS economies along with the existence of the environmental Kuznets curve (EKC) hypothesis. In addition, Magazzino et al. (2021) reveals that even in the recent Covid-19 pandemic period, the use of renewable energy may help sustain economic growth in Brazil. Besides these studies, there are number of empirical researches that also demonstrates the positive association of renewable energy consumption and economic growth (see for instance Apergis & Payne, 2010; Pao & Fu, 2013; Bhattacharya et al., 2016; Grabara et al., 2021; Usman et al., 2021).

On the other hand, Doytch and Narayan (2021) investigated both developed and developed economies and concludes that renewable energy is complementary to non-renewable energy in the high-income countries, while these two are substitutes in the middle-income economies. Using a sample of 103 economies, Chen et al. (2020) found that the influence of renewable energy on economic growth is mixed across countries. That is, using renewables above the threshold level enhances economic growth in the developing economies, and vice versa. While no significant impact of renewable energy is found in case of the developed economies except for the OECD countries, which is positive and linear. On the contrary to these studies, Baz et al. (2021) investigated the period of 1980-2017 in case of Pakistan and employed the non-linear autoregressive distributed lags (NARDL) model. The estimated results reveal that non-renewable energy enhances economic growth, whereas the reduction of renewable energy encourages economic growth in the country – demonstrating the negative impact of renewable energy consumption on economic growth. Also, the study indicates bidirectional causal nexus between renewable energy and economic growth. In addition, the study of Ocal and Aslan (2013) provides empirical evidence for the negative impact of renewable energy on economic growth in the case of Turkey. Besides, the study also validates unidirectional causal influence from economic growth to renewable energy consumption. Moreover, Abbasi et al. (2020) reveals the asymmetric impact of renewable energy on economic growth, where the negative shock in renewable energy could help boosting economic growth in the case of Pakistan.

Concerning the association of environmental related technologies and environmental related taxes, Shahzad et al. (2021) examined developed economies over the period 1994-2018. Using fully-modified ordinary least square (FMOLS) and quantile regression, the study found that environmental related technologies and environmental related taxes positively and significantly affects renewable energy generation. Several researches have shown that while environmental or pollution taxes may not always assist reduce energy consumption, they might help develop certain crucial measures for energy efficiency (Andreoni, 2019; Morley, 2012). He et al. (2019a) studied the link between environmental taxes of OECD countries and energy efficiency and discovered that eco-friendly technologies had a favorable impact on energy efficiency. Additionally, the study of Morley (2012) used the generalized method of moments (GMM) approach to explore the effects of environmental taxes on energy usage in European (EU) economies, and observed that environmental taxes have no substantial influence on consumption of energy in the region. Numerous earlier researches have highlighted the poor relationship between energy usage and environmental taxes in EU economies (Ekins & Speck, 1999; Morley, 2012). The study of Borozan (2019) used a fixed panel regression model to find how environmental taxes produce a massive rise in energy usage for EU member economies with lower energy use, whereas they cause an insignificant decrease in energy use for advanced EU economies. None the less, governments implemented environmental related taxes and stringent environmental in order to reduce pollution level and promote environmental sustainability. Yet, environmental taxes have been shown in several studies to be effective in lowering carbon and greenhouse gas emissions (Freire-González, 2018; He et al., 2019b, 2019c; Metcalf, 2018; Vera & Sauma, 2015). Hashmi and Alam (2019) used fixed effect and GMM models to look at the influence of environmental-related innovations as well as environmental related taxes on reducing emissions in OECD economies. The empirical results suggest that environmental taxes lower carbon emissions. Other research (He et al., 2019b, 2019c) found similar outcomes for developed economies such as OECD and G7 countries and developing economies like China, and Nordic.

Energy efficiency and renewable energy is currently a topic of concern among scholars and researchers. Specifically, the recent study of Kolosok et al. (2021) examined 28 EU economies throughout 1990-2018 via performing statistical analysis on python. The estimated results asserted that renewable energy and energy efficiency indicators are positively associated, except for energy productivity. Additionally, the study of Wang et al. (2020) empirically analyzed the factors that influences growth of renewable energy consumption in Group of twenty (G20) economies. The study found that research and development investment significantly enhance renewable energy consumption, followed by policy degree and energy efficiency, that helps promote renewable energy consumption. On the other hand, Dhakouani et al. (2019) demonstrated two scenarios in case of the Tunisia's renewable energy diffusion by revealing that a significant degree of renewable energy adoption, as well as a reduction in power system dependency is possible due to energy efficiency measures. The positive association of these two variables are due to the fact that improved energy efficiency substantially reduces energy use (Abolhosseini et al., 2014). Beside the association of energy efficiency and renewable energy, these two are also the significant factors of reducing pollution emissions in developing economies (Akram et al., 2020a, 2020b). Where Gielen et al. (2019) specified that energy efficiency and renewable energy will rise to 63% in 2050 as compared to the level of 2015, which will reduce carbon emissions up to 94% globally.

The recent study of Wang et al. (2022) investigated the influence of country risk on consumption of renewable energy as well as economic growth in OECD countries over the period 1997-2015. The study found that country risks (Composite, political, economic, financial) are positively associated to renewable energy consumption after achieving a threshold level of risk. Further, the study of Gatzert and Kosub (2017) explores various determinants regarding policy risks of investment in renewable energy. Beside the association of risk index and renewable energy consumption, the recent study of Khan et al. (2021) demonstrates that lower composite risk index and renewable energy adoption significantly reduces environmental degradation in RCEP economies. On the other hand, Hassan et al. (2022) analyzed the same region and contradicts the latter study by unveiling that lower composite, economic, and financial risks significantly enhance environmental degradation in the region.

2.2. Literature gap

The above discussion clearly mentioned that economic growth significantly affects renewable energy consumption. However, this influence is asymmetric, since the authors provide contradictory results (see for instance Mohsin et al., 2021; Li et al., 2021; Chen et al., 2020; Baz et al., 2021). Specifically, the earlier studies provide empirical evidence regarding the positive role of economic growth in renewable energy consumption, while the latter claimed its negative impact. Based on such contradictions in various developed and developing regions, a research gap is sustained which needs empirical investigation to identify the true impact of economic growth on renewable energy in the G7 economies, which is still missing in the literature. In addition, there are several studies that empirically examine the influence of energy efficiency, environmental related technological innovation, environmental taxes, and composite risk on several environmental indicators such as carbon or greenhouse gas emissions. Still, a very limited literature covers the association of these variables with renewable energy consumption. Also, the literature is silent concerning the said association in case of the most industrialized economies, i.e., G7 economies. Therefore, a research gap is identified in the literature, which must be filled to provide appropriate policy suggestions. Hence, this study attempts to identify the association of the said variables in the G7 economies. Unlike the previous studies, this study not only considers the unexplored factors of renewable energy consumption, but also uses advance econometric techniques to provide efficient and robust estimates.

3. Data and methodology

3.1. Theoretical framework and model construction

The history of economics shows that the services sector's proportion of national revenue has progressively expanded, which boosts the sector's energy consumption. Without energy consumption, the production of goods is not possible. Therefore, economies across the globe utilizes their substantial share of GDP towards energy consumption. However, countries usually one of the two measures; that is, either economies consider higher economic development and/or the environmental recovery. Specifically, if a country is more diverted towards economic development, they may prefer the use of non-renewable energy, which although boosts productivity of the industrial sector, but also enhances environmental degradation. On the other hand, if these economies are more concerned about environmental recovery, they may prefer renewable energy consumption, which initially requires higher transition cost, but could enhance economic growth and reduce environmental degradation. Thus, economic growth could play a substantial role in renewable energy consumption which must be empirically analyzed.

Energy efficiency is a critical strategic tool for disconnecting economic development from carbon emissions and alleviating ecological damage. Energy efficiency literally implies generating the same amount of product with less energy. Increasing investment in policies to attain energy efficiency may have a variety of advantages. When energy efficiency is accomplished, it may promote environmental sustainability, decrease the stress on the environment by lowering carbon emissions, reduce the fossil fuel demand, increase energy security, ameliorate power shortages, and stimulate industrial rivalry by lowering operating costs. Furthermore, energy efficiency is a critical component for adopting clean and green development policies in industrialized countries, such as renewable energy generation and consumption, which aim to reduce carbon emissions via increased energy utilization. Finally, from a global viewpoint, achieving sustainable development goals requires making greater use of improved energy efficiency. As a result, increasing energy efficiency is a major goal for developed economies such as the G7 countries in order to sustain industrialization, relieve energy shortages, and mitigate the effects of carbon emissions. Hence, it is conceivable that energy efficiency has a significant association with renewable energy consumption.

In addition, technological advancements that increase dependence on capital may raise energy consumption per unit of production since more energy is needed to operate extra equipment. However, after the development of environmental-related technologies, energy may be utilized more effectively than in the past. It has specifically allowed for the use of alternative energy sources with a lower environmental effect. According to a recent Harvard University study, developments in renewable energy equipment such as batteries might lead to more efficient and cost-effective renewable energy systems. According to the study, by employing new batteries, expenses may be decreased while more energy can be stored. Such research is boosting industrial excitement, but private companies are also investing in innovative technology. As a result, environmental-related technologies could not be ignored while investigating renewable energy consumption. On the other hand, environmental related taxes could also play a significant part in the construction and implementation of environmentally friendly energy resources. An increase in the environmental taxes could help reduce the excessive use of traditional fossil fuel and leads to enhance productivity via renewable energy. Therefore, environmental related taxes could be considered in the empirical examination of renewable energy consumption. Lastly, a composite risk index is a qualitative or quantitative indicator created from multidimensional parameters that may reflect a country's, industry's, or firm's relative performance in a certain area. A composite index is ideally a simple mathematical number derived from the aggregation of a set of complicated information. Once created, a composite index may be used to encourage interaction, comparisons, strategic planning, ranking and benchmarking. Hence, composite risk index could also influence renewable energy consumption, which needs empirical evidence for its real influence on renewable energy.

Based on the theoretical notion, this study used a total of seven variables, where the dependent variable is renewable energy consumption (*REC*). However, the most frequent determinants of the *REC* in the prior literature is notes as economic growth

Table 1. Variables' specification and data sources.

Variable	Specification	Data Source
REC	The proportion of gross inland *REC* to total (primary) gross inland energy consumption determined over a calendar year and measured as a % of total energy consumption.	https://databank.world-bank.org/source/world-development-indicators
GDP	The total market value of all final services and goods, measured in constant US$ 2010 prices.	https://databank.world-bank.org/source/world-development-indicators
DERTI	Technological innovation that addresses climate change and is measured as a % of total innovation.	https://stats.oecd.org/
ENVTX	A tax wherein tax base is a tangible unit (or a proxy for one) that has been shown to have a particular negative environmental impact.	https://stats.oecd.org/
CRI	A risk value determined by combining all safety-related occurrences that have been recorded, analyzed, and severity categorized and measured as index out of 100.	https://www.prsgroup.-com/explore-our-products/international-country-risk-guide/
ENEF	Energy saving or using less energy to perform similar task and is measured as GDP per unit of energy use (PPP $ per kg of oil equivalent).	https://databank.world-bank.org/source/world-development-indicators
ENEFS	Squared of *ENEF*.	https://databank.world-bank.org/source/world-development-indicators

Source: collected by the authors.

– captured by *GDP*, environmental related technological innovation (*DERTI*), environmental taxes (*ENVTX*), composite risk index (*CRI*) and energy efficiency (*ENEF*). Whereas most of the studies considers the influence of improved energy efficiency on renewable energy consumption (Dhakouani et al., 2019; Kolosok et al., 2021). Also, the importance of improved energy efficiency is reported in terms if reduction in carbon emissions (Gielen et al., 2019). Therefore, this study also considered the squared energy efficiency to identify the association of improved energy efficiency on renewable energy in developed economies. Data for all these variables are obtained from multiple sources, covering the group of seven economies including Germany, Canada, France, the UK, Japan, Italy, and the US. The time period for the said variables and countries are for the last three decades and is selected based on the availability of data. The specifications of variables and data sources are displayed in Table 1:

Following the study of Wang et al. (2020), this study constructed the following two models, where energy efficiency and the squared of energy efficiency is taken in two separate models:

Model-1

$$REC_{it} = f(GDP_{it}, DERTI_{it}, ENVTX_{it}, CRI_{it}, ENEF_{it})$$

Model-2

$$REC_{it} = f(GDP_{it}, DERTI_{it}, ENVTX_{it}, CRI_{it}, ENEF_{it}, ENEFS_{it})$$

In order to empirically analyze these models, they can get the following regression form:

$$REC_{it} = \alpha_1 + \alpha_2 GDP_{it} + \alpha_3 DERTI_{it} + \alpha_4 ENVTX_{it} + \alpha_5 CRI_{it} + \alpha_6 ENEF_{it} + \varepsilon_{it} \quad (1)$$

$$REC_{it} = \beta_1 + \beta_2 GDP_{it} + \beta_3 DERTI_{it} + \beta_4 ENVTX_{it} + \beta_5 CRI_{it} + \beta_6 ENEF_{it} + \beta_7 ENEFS_{it} + \varepsilon_{it} \quad (2)$$

Where the above Eq. (1) reveals that *GDP*, *DERTI*, *ENVTX*, *CRI*, and *ENEF*, are the function of *REC*. While Eq. (2) reveals that the prior variables along with the *ENEFS* are the influencing factors of *REC*. Besides, α'*s* and β'*s* are the coefficient to estimate. In addition, "*i*" and "*t*" are the cross-sections and time period, while ε is the random error term.

3.2. Estimation strategy

3.2.1. Descriptive statistics and normality test

Prior to empirical estimation of the data under consideration, this study provides descriptive statistics that helps summarize the data. In this regard, the estimates for mean, median and range values are evaluated. Besides, we also estimate the value of standard deviation that reveals the variation of each specific observation from the mean value and also indicates volatility in a variable. In order to test for normality of the data, we use two measures, i.e., skewness and Kurtosis. Whereas, the extensive measure of data's normality is also employed for comprehensive measure of the data distribution. In this sense, we employed the Jarque and Bera (1987) normality test, which is presented in the standard form as follows:

$$J.B = \frac{N}{6}\left(S^2 + \frac{(K-3)^2}{4}\right), \quad (3)$$

Where the equation above reveals that *N* is the number of observations, *S* is skewness and *K* indicates excess Kurtosis. This test is more effective than that of the separate analysis of skewness and Kurtosis as it considers both the skewness and excess Kurtosis at the same time. While the null hypothesis assumes that both the said estimates must be equal to zero in a Jarque-Bera test and demonstrates the normal distribution of the data. However, if the estimated results are significant, the null hypothesis could be rejected to concludes that the data is not normally distributed.

3.2.2. Slope heterogeneity and cross-sectional dependence

After employing the normality test, this study analyzes the panel data specifications such as slope coefficients heterogeneity and cross-section dependence. After the industrial between 1760 and 1840, globalization and international trade enhances with a rapid pace, that lead some economies specialize in some products and other countries in some other products and services. Due to this specialization process, some economies are found dependent on other economies for various financial, economic, environmental, and technological development reasons. As a consequence, economies adopted policies in response of dependence, that one economy implement policies that could result in similarity to other economies, that create the issue of slope homogeneity which is a sensitive issue in an econometric investigation. If the slope homogeneity issue exists in a panel data estimation process, the resulted estimates may be inefficient and misleading (Breitung, 2005; Le & Bao, 2020). To deal the issue, this study utilizes the slope coefficient heterogeneity (SCH) test proposed by Pesaran and Yamagata (2008). This test is efficient as it provides the estimated values for both the SCH an adjusted SCH (ASCH), which could be obtained via the following two equations:

$$\hat{\Delta}_{SCH} = \sqrt{N.(2k)^{-1}}(N^{-1}\acute{\text{S}} - \text{K}), \tag{4}$$

$$\hat{\Delta}_{ASCH} = \sqrt{N}\sqrt{\frac{T+1}{2K(T-K-1)}}.(N^{-1}\acute{\text{S}} - 2\text{K}), \tag{5}$$

From above Eq. (3), $\hat{\Delta}_{SCH}$ is the slope coefficient homogeneity and from Eq. (4), $\hat{\Delta}_{ASCH}$ indicates adjusted slope coefficient homogeneity. Where the null hypothesis demonstrates that the slope coefficients are homogenous across the panel, which could only be rejected if the estimated results are statistically significant.

Globalization and trade across borders as previously mentioned, enhances one country's specialization in particular goods and/or services, which could be of greater demand in other countries and nations. Consequently, the dependency of these economies on such specialized economies further increase. In this case, if the G-7 economies are cross-sectionally dependent, we have to use an effective estimator that could allow for cross-section dependency as ignoring such panel issue could lead to inconsistent estimates in empirical investigation (Campello et al., 2019). Hence, we use the Pesaran (2021) cross-sectional dependence (CD) test to analyze if there exist cross-sectional dependency in the G-7 economies. The standard equation for estimating cross-dependency is provided as following:

$$\text{CD}_{Test} = \frac{\sqrt{2T}}{[N.(N-1)]^{1/2}}\sum_{i=1}^{N-1}\sum_{k=1+i}^{N} T_{ik} \tag{6}$$

The null proposition of this test reveals that the cross-sections are independent throughout the panel. However, significant estimates are enough evidence to reject the null proposition and concludes that there exists cross-sectional dependency in the panel.

3.2.3. Testing for unit root

The existence of cross-sectional dependency in the panel and heterogenous slope coefficients allows this study to use appropriate estimator that could tackle both the panel data problems. Therefore, we used cross-sectionally augmented IPS (CIPS) test proposed by Pesaran (2007). Earlier, Pesaran (2006) provided a factor modelling technique to tackle cross-section dependency. Where this approach considers merging of cross-sectional averages into the model as a representation of common unobserved components. Following this approach, Pesaran (2007) demonstrates a unit root testing specification while using the mean and first difference of lagged cross-sections for expansion of the Augmented Dickey-Fuller (ADF) regression. This specific method offers precise results due to the power of tackling cross-section dependence even if the panel is unbalanced (T > N or N > T). The regression formulation of the cross-section ADF is presented as follows:

$$\Delta y_{i,t} = \theta_i + \beta_i^* y_{i,t-1} + d_0 \overline{y}_{t-1} + d_1 \Delta \overline{y}_t + \varepsilon_{it}, \tag{7}$$

Where Eq. (6) shows that $\overline{y}_t$ is the average of N observations. In order to tackle the issue of serial correlation, the first differenced lags of $\overline{y}_t$ and y_{it} could be added to Eq. (7), which adopts the new form as given below:

$$\Delta y_{it} = \theta_i + \beta_i^* y_{i,t-1} + d_0 \overline{y}_{t-1} + \sum_{j=0}^{n} d_{j+1} \Delta \overline{y}_{t-j} + \sum_{k=1}^{n} c_k \Delta y_{i,t-k} + \varepsilon_{it}, \tag{8}$$

Hence, the Pesaran (2007) CIPS could be determined in the G-7 panel while utilizing the average t-statistics for every individual (cross-section) unit ($CADF_i$). The equation form for the estimating CIPS could be expressed as follows:

$$CIPS = N^{-1} \sum_{i=1}^{N} CADF_i, \tag{9}$$

The Pesaran (2007) CIPS test assumes the presence of a unit root as a null proposition, which may be accepted if the statistical values are insignificant.

3.2.4. Testing for cointegration

To examine the long-run cointegration association between the variables of the selected panel, this study employed the Westerlund (2007) error correction model (ECM). This test provides efficient estimates for the reason of high power in tackling the cross-sectional dependence as well as slope heterogeneity by incorporating the panel statistics and the group mean statistics. The standard form of evaluating both the said statistics are provided as follows:

The mean group statistics are $G_\tau = \frac{1}{N}\sum_{i=1}^{N} \frac{\hat{\alpha}_i}{S.E\hat{\alpha}_i}$, and $G_a = \frac{1}{N}\sum_{i=1}^{N} \frac{T\hat{\alpha}_i}{\hat{\alpha}_i(1)}$, whereas panel statistics could be obtained as, $P_\tau = \frac{\hat{\alpha}}{S.E(\widehat{\alpha})}$, and $P_a = T.\hat{\alpha}$.

3.2.5. Method of movement quantile regression

Initially, the panel quantile regression is proposed by Koenker and Bassett (1978), where conditional mean and dependent variance are estimated regarding the explanatory parameters' value. In a panel data estimations process, if the dataset satisfies the properties of abnormal distribution, the quantile regression gives efficient estimates. Since the data under consideration also holds the property of abnormal distribution, therefore we utilized the novel method of moments quantile regression (MMQR) approach proposed by Machado and Silva (2019). This novel method is formed to analyze the distributional as well as heterogenous properties of quantile numbers (Sarkodie & Strezov, 2019). To be more specific, the conditional quantile location-scale $Q_y(\tau|X)$ variant approximations may be obtained via standard equation, given as:

$$Y_{it} = \theta_i + \vartheta X_{it} + \left(\delta_i + \rho.\acute{Z}_{it}\right)\mu_{it}, \tag{10}$$

The above equation sows the probability $P\left(\delta_i + \rho.\acute{Z}_{it} > 0\right) = 1$. Whereas θ, ϑ, δ, and ρ the coefficients to estimates. In addition, the subscript (i) demonstrates fixed effect, as recommended by θ_i and δ_i (i.e., $i = 1, 2, \dots, n$) and the k-vector of standard elements of X is denoted by Z, which is a distinctive alteration with component $\lessdot$, given below:

$$Z_{\lessdot} = Z_{\lessdot}(X), \ \lessdot = 1, \ 2, \ \dots, \ k \tag{11}$$

Where X_{it} is independently as well as identically distributed for every fixed i and t (time). In the same way, μ_{it} is orthogonal to X_{it}, which is scattered throughout time and fixed cross-sections (Machado & Silva, 2019). This also helps in stabilization of components persisting and prevent extreme exogenous behavior. Thus, Eq. (1) and Eq. (2) could adopt the following general form:

$$Q_y(\tau X_{it}) = (\theta_i + \delta_i q(\tau)) + \vartheta X_{it} + \rho \acute{Z}_{it} q(\tau), \tag{12}$$

Here the Eq. (12) reveals that X_{it} is the explanatory variables' vector, including *GDP*, *DERTI*, *ENVTX*, *CRI*, and *ENEF* in model-1 [Eq. (1)], with the addition of *ENEFS* in Model-2 [Eq. (2)], and the natural log form is taken into consideration for empirical analysis. Besides, the left-hand side (LHS) of the above equation shows the dependent variable's quantile distribution, i.e., Y_{it} and captured *REC* in this case, which could be described as conditional on X_{it} and on the location of explanatory variables. Moreover, $-\theta_i(\tau) \equiv \theta_i + \delta_i \ q(\tau)$, is the scalar coefficient which is the fixed effect of τ quantiles for specific cross-section (i). in distinction to the existing least square fixed effects, the individual effect does not pose shift in the intercept. Heterogeneous effects are likely to modification and conditional distribution across quantiles since the variables are time-invariant. Lastly, $q(\tau)$ signifies the quantiles' τ-th sample, which this study considers as four, that is, 25^{th}, 50^{th}, 75^{th}, and 90^{th} to analyze the concerned issue. In order to estimate each specific quantile, the quantile equation used in this study could be presented as follows:

$$min_q \sum_i \sum_t \gamma_\tau \left(R_{it} - \left(\delta_i + \rho \acute{Z}_{it}\right).q\right), \tag{13}$$

Where $\gamma_\tau(A) = (\tau - 1)AI\{A \leq 0\} + TAI\{A > 0\}$, uncovers the check function.

3.2.6. Panel causality test

Since the MMQR approach provides the estimated output for each explanatory variable at a specific location and scale, whereas it lacks to provide the causal association exist between the variables under-consideration. Concerning, this study utilized the Dumitrescu and Hurlin (2012) Granger panel causality heterogeneity test for causality identification. This test is more efficient as it is more powerful in tackling the issue of unbalanced panel ($T \neq N$). Moreover, this test also deals the panel data issue of heterogeneity and cross-sectional dependence (Banday & Aneja, 2020).

Table 2. Descriptive statistics and normality check.

	REC	*GDP*	*DERTI*	*ENVTX*	*CRI*	*ENEF*	*ENEFS*
Mean	0.842934	12.51056	0.947816	1.867704	1.891599	0.861168	0.774587
Median	0.871322	12.42700	0.972203	1.885329	1.894293	0.864897	0.748047
Maximum	1.357361	13.26246	1.187239	1.937909	1.938791	1.187460	1.410061
Minimum	−0.215908	11.99614	0.674861	1.768978	1.298320	0.493295	0.243340
Std. Dev.	0.372551	0.312759	0.134223	0.048133	0.048284	0.182014	0.311193
Skewness	−0.720966	0.867561	−0.278807	−0.646755	−8.656224	−0.132619	0.235767
Kurtosis	3.191111	2.971194	1.929501	2.089780	106.2840	2.202937	2.147473
Jarque-Bera	19.12936	27.22881	13.17283	22.61927	99162.75	6.380346	8.581874
Probability	0.000070	0.000001	0.001379	0.000012	0.000000	0.041165	0.013692

Source: collected by the authors.

4. Results and discussion

4.1. Results interpretation

In this section, the outcomes for descriptive statistics and normality test are provided prior to empirical investigation. Table 2 reports the descriptive statistics and normality test results. Specifically, the mean and median values are found approximately the same (having little difference) and also positive. This demonstrates that all the variables, i.e., *REC*, *GDP*, *DERTI*, *ENVTX*, *CRI*, *ENEF*, and *ENEFS* are following the increasing trend in the G7 economies. Since the selected panel economies are the most industrialized economies across the globe. Therefore, these countries are progressive in their economic growth, renewable energy consumption, environmental related innovation's development, and energy efficiency. Beside these, environmental related taxes are also in positive motion, where the composite risk index is also followed the positive path. Since the computed results reveal that the minimum and maximum values although hold positive signs for all the variables except for renewable energy, but also possess substantial difference. Yet, only the renewable energy is found in negative, with the minimum value of −0.2159. The considerable difference between the observations from the mean value is captured by the standard deviation value of each variable. Such values also demonstrate volatility in the variable throughout time, indicating that *REC*, and *GDP* are the most volatile in the variables under consideration. Moreover, the skewness and Kurtosis values are found non-similar to their proposed values, i.e., 1 and 3, respectively. While the normality of the variables is comprehensively measured via employing the Jarque and Bera (1987) normality test. The statistical values for each study variable are found highly statistically significant (p-value < 0.05). Therefore, the null hypothesis normal distribution of the said test will be rejected and concludes that the data follows irregular path over the selected time period.

Once the normality test estimates are evaluated, this study further explores the slope heterogeneity of the panel, estimates are reported in Table 3. The estimates for both models asserted that the statistics of SCH and ASCH are highly statistically significant at 1% level. This is enough evidence to decline the null hypothesis of slopes homogeneity. Instead, the results conclude that the slope coefficients of the panel are heterogenous.

Since the cross-section dependence is an existing issue in most of the panel studies, whereas Campello et al. (2019) suggested that ignoring such panel data issue may

Table 3. Slope heterogeneity.

Slope Heterogeneity Test	Statistics
Model-1	
$\tilde{\Delta}$	13.952***
$\tilde{\Delta}_{\text{Adjusted}}$	16.198***
Model-2	
$\tilde{\Delta}$	10.436***
$\tilde{\Delta}_{\text{Adjusted}}$	12.388***

*Note: Significance level is denoted by *** for 1%, ** for 5% and * for 10%.*
Source: collected by the authors.

Table 4. Cross-section dependence.

Cross-Section Dependence	
REC	***GDP***
20.76***	24.013***
DERTI	***ENVTX***
23.606***	3.192***
CRI	***ENEF***
13.53***	25.234***
ENEFS	
25.306***	

*Note: Significance level is denoted by *** for 1%, ** for 5% and * for 10%.*
Source: collected by the authors.

cause estimation bias and provides misleading results. Therefore, this study employed the Pesaran (2021) CD test and the estimated outcomes are reported in Table 4. The results indicate that all the variables are highly statistically significant, which is evidence enough for the null proposition rejection. In other words, the significant estimates reject the null hypothesis of independent cross-sections and conclude that the cross-sections of the G7 panel economies are dependent. That is, economic growth, renewables' consumption, and other variables under-consideration for one country possess a spillover effect on the same variables of other economies. Hence, to estimate further empirical results, a second-generation test will be used to tackle slope heterogeneity and cross-section dependence.

Since the SCH and CD tests validates that slope coefficient heterogeneity and cross-section dependence in the panel, therefore this study employed the Pesaran (2007) stationarity testing approach. This test is efficient in dealing both the mentioned panel data problems. The estimated results of test under-taken are provided in Table 5. The results reveal that all the variables are stationary while following mixed order of integration. To be more specific, five of the total variables, i.e., *REC*, *DERTI*, *CRI*, *ENEF*, and *ENEFS* are found stationary at I(0), while *GDP*, and *ENVTX* are insignificant at level. However, these variables are further checked on I(1), which found that the variables are stationary. This allows us to examine the long-run association between the variables under study.

In order to analyze the cointegration relationship between the variables considered in this study, we employed the Westerlund (2007) error correction model (ECM) approach, and the estimated results are provided in Table 6. The results are provided for both the models constructed. Where the empirical findings asserted that both the group mean statistics (G_τ and G_a) and the panel statistics (P_τ and P_a) are statistically

Table 5. Unit root testing (Pesaran, 2007).

	Intercept and Trend	
Variables	I(0)	I(1)
REC	−3.260***	–
GDP	−2.182	−4.142***
DERTI	−3.857***	–
ENVTX	−2.200	−5.065***
CRI	−5.866***	–
ENEF	−2.775*	–
ENEFS	−3.039**	–

Note: Significance level is denoted by *** for 1%, ** for 5% and * for 10%. I(0) is for level, and I(1) is for the first.
Source: collected by the authors.

Table 6. Cointegration results (Westerlund-2007).

Model-1		
Statistics	Value	Z-value
G_τ	−3.424***	−3.186
G_a	−15.791*	−1.402
P_τ	−7.680**	−2.211
P_a	−26.548***	−6.160
Model-2		
G_τ	−3.959***	−3.975
G_a	−15.137	−0.405
P_τ	−9.940***	−3.617
P_a	−14.134	−1.247

Note: Significance level is denoted by *** for 1%, ** for 5% and * for 10%.
Source: collected by the authors.

Table 7. Estimates of quantile regression–MMQR Model-1.

Dep. Var.:			Quantiles			
REC	Location	Scale	$Q_{0.25}$	$Q_{0.50}$	$Q_{0.75}$	$Q_{0.90}$
GDP	−0.265***	−0.073*	−0.190**	−0.298***	−0.327***	−0.347***
	[0.064]	[0.044]	[0.096]	[0.022]	[0.055]	[0.056]
ENEF	−0.0536***	0.123	−0.661***	−0.480***	−0.432***	−0.399***
	[0.119]	[0.076]	[0.184]	[0.099]	[0.088]	[0.092]
DERTI	1.819***	−0.595	2.426***	1.545***	1.313***	1.152***
	[0.182]	[0.121]	[0.330]	[0.151]	[0.105]	[0.110]
ENVTX	0.074	0.709**	−0.650	0.401	0.678**	0.869***
	[0.417]	[0.328]	[0.714]	[0.334]	[0.290]	[0.309]
CRI	0.753**	−0.036	0.789*	0.736**	0.723**	0.713**
	[0.351]	[0.166]	[0.460]	[0.318]	[0.303]	[0.301]
Constant	1.330***	0.349*	0.974	1.491	1.627	1.721
	[1.604]	[1.165]	[2.520]	[1.336]	[1.253]	[1.286]

Note: The dependent variable used here is REC. Significance level is denoted by ***, ** and * for 1%, 5% and 10%.
Source: collected by the authors.

significant – rejecting the null hypothesis and concludes that the cointegration association exists between the variables. On the other hand, the group mean statistic (G_τ) and the panel statistic (P_τ) are highly significant at 1% level. Thus, the null proposition of no cointegration or the error correction equals zero could be rejected for both the models. Hence, it is assumed that the error correction exists in both models, which concludes that the cointegration exists between the variables under consideration.

Once the empirical results of cointegration is obtained, this study analyzed the specific influence of each explanatory variable on *REC* by employing MMQR approach. The estimated results are displayed in Table 7. The results are evaluated for all the variables under consideration at four different quantiles, i.e., $Q_{0.25}$, $Q_{0.50}$, $Q_{0.75}$, and $Q_{0.90}$. The empirical results reveal that *GDP* and *ENEF* negatively affects *REC*. In other words, a one percent increase in *GDP* significantly reduces *REC* by 0.190–0.347% from lower ($Q_{0.25}$) to higher ($Q_{0.90}$) quantiles. These results are statistically significant to the existing study of Chen et al. (2020) in a sample of 103 economies, Baz et al. (2021) in case of Pakistan and Ocal and Aslan (2013) in case of Turkey. As mentioned earlier, the under-study panel of G7 economies are the most developed and industrialized economies across the world. Therefore, these countries are more progressive towards sustenance of economic growth, rather than renewable energy deployment. In order to maintain the trade balance or surge exports, these economies expand production via technological innovation that is more fossil fuel oriented. Hence, the economic growth, on the one hand moves in the upward direction, yet the renewable energy consumption is declining due to the fact of achieving and maintaining higher income growth. In the similar way, *ENEF* is found in negative association with *REC*. In particular, enhancement of one percent in the *ENEF* significantly reduces *REC* by 0.661 and 0.399 percent in the lower and higher quantiles. However, the magnitude of the influence is found greater i.e., −0.480 and −0.432 in the medium quantiles ($Q_{0.50}$ and $Q_{0.75}$, respectively). These findings statistically significant at 1% levels in all the quantiles and are contrary to the existing studies of Kolosok et al. (2021) in case of 28 EU economies, and Wang et al. (2020) G20 economies. Since the developed (G7) economies are maintained economic growth and are involved in rapid production and industrial expansion, therefore enhancement in the energy efficiency and related technologies are more cost-effective, that encourages energy saving, rather than deploying renewable energy.

On the other hand, *DERTI*, *ENVTX*, and *CRI* are found in positive association to *REC*. An increase of one percent in *DERTI* enhances *REC* by 2.426–1.152% at 1% level of significance. Where the magnitude of the influence is found decreasing from lower to higher quantile. Also, *ENVTX* is found in positive association to the *REC*, but significant only in the higher quantiles, which is notice in increasing trend from medium ($Q_{0.75}$) to upper quantile ($Q_{0.90}$). Specifically, an increase of one percent in *ENVTX*significantly increase the use of *REC* by 0.678 and 0.869%, respectively. These estimates showed consistency to the earlier study of Shahzad et al. (2021) in developed economies by providing evidence of increase environmental taxes and environmental related technological innovation enhances renewables consumption. Also, the study of He et al. (2019a) in OECD economies is found consistent to current findings by demonstrating that eco-friendly technologies are favorable in terms of adopting energy-saving products and services, that also reduces pollution emission in the region. On the other hand, these results are different than the studies of Morley (2012) and Borozan (2019), that identified environmental taxes are insignificantly related to the energy use in the EU economies. Since environmental taxes and environmental related technological innovations are encouraged and implemented to reduces carbon and GHG emissions in the country. Therefore, the prominent factor

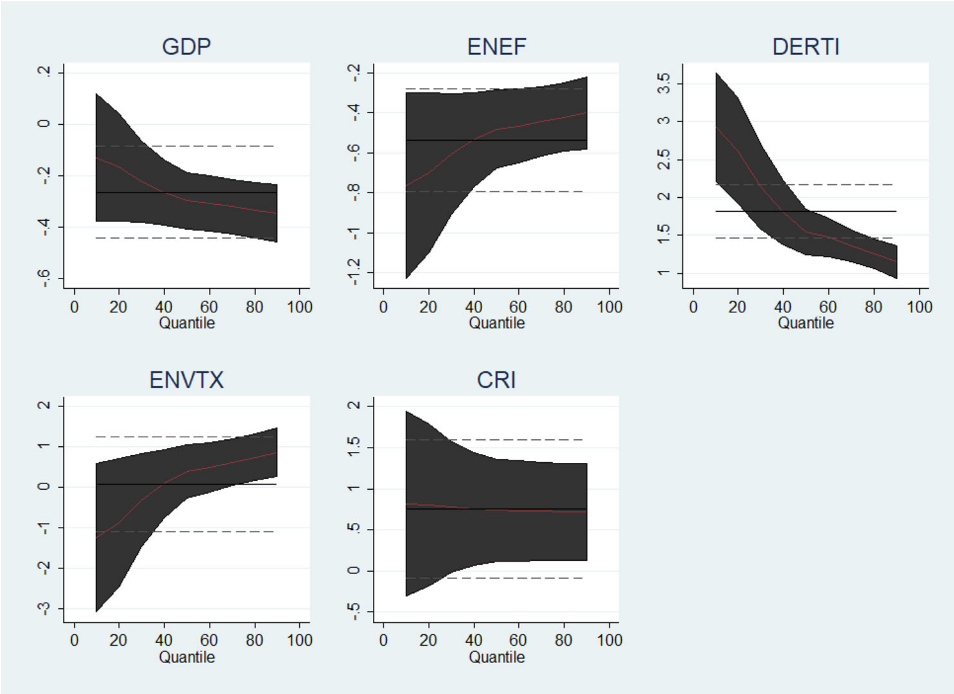


Figure 3. Graphical representation of quantiles for model-1.
Source: drawn by the authors.

that leads to environmental sustenance without affecting economic growth is the use of environmentally friendly energy, i.e., renewable energy consumption. On the one hand, renewable energy maintains or fulfill the demand for energy, and reduces environmental pollution (Hashmi & Alam, 2019). Therefore, both these measures are critical for accomplishing energy demand as well as pollution reducing targets. Moreover, the *CRI* are noted in positive association to *REC*, specifically, if the *CRI* is increased by one percent, the *REC* also enhances by 0.789–0.713% across the quantiles, while moving from lower to upper quantile, the magnitude of the influence reduces but the significance level increases, which are in line to the study of Wang et al. (2022). Concerning the *CRI*, enhancement in the risk factors is more energy oriented. In other words, encouragement of the composite risk contributes to the financial development, where the developed financial sectors are the key factors of provision in the green loans and renewable energy consumption. Thus, the industrial sectors are diverted to the use of renewable energy in the higher level of *CRI*, which helps reduce carbon and pollution emissions in the RCEP economies (Khan et al., 2021). The empirical estimates for each observed variable in the Model-1 is displayed in graphical representation as shown in Figure 3.

In the second model of the study, the empirical estimates of MMQR found the similar association of variables such as *GDP*, *DERTI*, *CRI*, and *ENEF* on *REC* as reported in Table 8. Yet a small difference has been observed in the magnitude of each variable. Still the direction of the influence remains the same. However, with the additional variable of *ENEF*S into the second model, the *ENVTX* becomes

Table 8. Estimates of quantile regression–MMQR Model-2.

			Quantiles			
Dep. Var.: REC	Location	Scale	$Q_{0.25}$	$Q_{0.50}$	$Q_{0.75}$	$Q_{0.90}$
GDP	−0.233***	−0.084**	−0.157*	−0.264***	−0.308***	−0.338***
	[0.062]	[0.040]	[0.086]	[0.058]	[0.056]	[0.059]
ENEF	−5.075***	2.121***	−7.003***	−4.299***	−3.177***	−2.433***
	[0743]	[0.463]	[1.154]	[0.698]	[0.562]	[0.570]
ENEFS	2.709***	−1.190***	3.791***	2.2739***	1.644***	1.226***
	[0.445]	[0.270]	[0.674]	[0.418]	[0.348]	[0.353]
DERTI	1.627***	−0.520***	2.099***	1.437***	1.162***	0.979***
	[0.177]	[0.097]	[0.274]	[0.167]	[0.125]	[0.115]
ENVTX	−0.324	0.526*	−0.802	−0.131	0.147	0.332
	[0.380]	[0.310]	[0.599]	[0.338]	[0.324]	[0.367]
CRI	0.898***	−0.112	0.999***	0.858***	0.799***	0.759*
	[0.267]	[0.232]	[0.337]	[0.281]	[0.339]	[0.394]
Constant	3.397**	0.090	3.316	3.430***	3.478**	3.509**
	[1.442]	[1.190]	[2.155]	[1.306]	[1.354]	[1.535]

Note: The dependent variable used here is REC. Significance level is denoted by ***, ** and * for 1%, 5% and 10%.
Source: collected by the authors.

insignificant. Nonetheless, the influence is positive in the last two quantiles, still it is insignificant to make substantial changes in *REC*. On the other hand, *ENEFS*, which is a squared term of *ENEF*, is found in positive association to *REC* in the G7 economies. Particularly, an increase of one percent in the *ENEFS* significantly enhances *REC* by 3.791–1.226%. Though the magnitude of the influence is found decreasing from lower quantile ($Q_{0.25}$) to higher quantile ($Q_{0.90}$). Still, the impact is statistically significant at 1% level in all the quantiles. These results are consistent to the earlier studies of Dhakouani et al. (2019) in case of Tunisia, Wang et al. (2020) in G20 economies, and Kolosok et al. (2021) in 28 EU economies. Since the developed nations, as compared to the developing economies are ore concerned about economic growth maintenance, and environmental sustainability. Therefore, developed and improved energy efficiency products and services are deployed to achieve such economic-environmental objectives. Enhanced energy efficiency is connected to the lower demand for energy consumption (Abolhosseini et al., 2014). However, this energy saving and energy efficient behavior of developed economies could a significant factor of reduced carbon and GHG emissions in the region (Akram et al., 2020a, 2020b). The influence of each explanatory variable in Model-2 across all the quantiles is visible in the Figure 4.

Once the specific influence of each explanatory variable is identified on *REC*, this study noted that the MMQR does not directed about the causal nexus of explanatory variables and dependent variable. In this regard, we employed the Dumitrescu and Hurlin (2012) Granger panel causality heterogeneity test on the panel data of G7 economies. The empirical results are displayed in Table 9. The obtained results asserted that there exist both bidirectional and unidirectional causal nexus between the variables. In other words, there is a unidirectional causal association found running from *GDP* and *CRI* to *REC*, which is consistent to the earlier study of Ocal and Aslan (2013) in the case of Turkey. This indicates that economic growth and composite risk are playing a prominent role in the *REC*. Therefore, these two variables could be essential policy tool for increasing *REC* in the G7 economies. On the other hand, the feedback effect is noted between the explanatory variables such as *DERTI*,

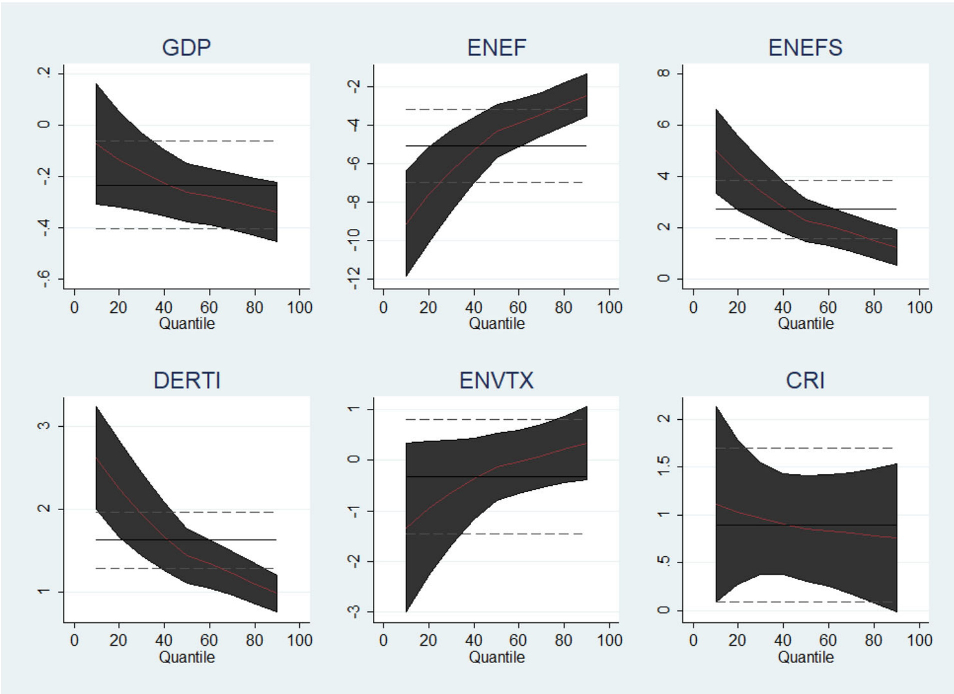


Figure 4. Graphical representation of quantiles for model-2.
Source: drawn by the authors.

Table 9. Dumitrescu-Hurlin panel causality.

H_0	$Wald_{Stats}$	$\bar{Z}_{stats}$	p − value
GDP – *REC*	6.508***	4.78907	2.E-06
REC – *GDP*	1.024	−1.28184	0.1999
DERTI – *REC*	9.617***	8.23110	2.E-16
REC – *DERTI*	4.79874***	2.89689	0.0038
ENVTX – *REC*	8.21998***	6.68412	2.E-11
REC – *ENVTX*	4.23214**	2.26967	0.0232
CRI – *REC*	4.41945***	4.26306	0.0000
REC – *CRI*	2.59797	0.46067	0.6450
ENEF – *REC*	9.64339***	8.25981	2.E-16
REC – *ENEF*	7.03182***	5.36886	8.E-08
ENEFS - REC	11.3053***	10.0995	0.0000
REC - ENEFS	6.70715***	5.00946	5.E-07

Note: Significance level is denoted by *** for 1%, ** for 5% and * for 10%.
Source: collected by the authors.

ENVTX, *CRI*, *ENEF*, *ENEFS* and *REC*. This reveals that all these variables are playing significant role in the renewable energy adaptation, and promotion in the G7 economies.

4.2. Discussion on the results

The empirical findings asserted that all the variables substantially affect renewable energy consumption in the G7 economies. Specifically, development of environmental related technological innovations, environmental related taxes, and composite risk index are the increasing factors of renewable energy consumption. In other words, enhancement in DERTI promote the culture of environmentally friendly energy resources, while reducing dependence on traditional fossil fuel consumption (Shahzad et al., 2021). Still, industries are using non-renewable energy resources to maximize the productivity level. In this regard, authorities and government impose heavy taxes on pollution intensive industries. Due to which they reduce the use of fossil fuel, and start transition towards renewable energy consumption, which not only maintain their productivity level, but also improves the quality of environment (He et al., 2019a). Moreover, economic growth also influences REC, but the direction of influence is negative. In this case, the G7 economies are more concerned about their economic sustainability than the environmental recovery. Therefore, the economic growth is more directed towards environmentally destructive policies, which not only reduces REC, but also promote environmental degradation as a biproduct (Baz et al., 2021; Chen et al., 2020). Therefore, the existing policies regarding REC must be upgraded and improved in favor of environmental recovery. Moreover, it is noted that the energy efficiency is not at the optimum level, due to which, energy efficiency significantly reduces REC. However, improved level of energy efficiency (i.e., ENEFS) significantly enhances REC (Kolosok et al., 2021; Wang et al., 2020). In this regard, these economies should pay more attention towards the strengthening of policies that should enhance energy efficiency by encouraging energy saving and energy efficient products and services, to enhance renewable's consumption.

5. Conclusion and policy implications

The prime aim of this study is to investigate the factors of renewable energy in the G7 economies during the last three decades while adopting advanced panel econometric approaches such as the second-generation unit root test, the novel MMQR, and panel causality approach. The empirical results validate the existence of long-run equilibrium relationship, where the estimates asserted that economic growth and energy efficiency adversely affects renewable energy consumption. In contrast, development in the environmental related technical innovation, environmental taxes, composite risk index and squared energy efficiency are positively contributing to renewable energy consumption in these countries, where the causality estimates validate this relationship.

Based on the empirical findings, this study provides policy suggestions that could play essential role in the G7 economies to enhance renewable energy consumption in the region. Firstly, the results report that economic growth adversely affects renewable energy consumption, which is alarming for such developed nations. Therefore, these economies should adopt policies that discourages the subsidization and promotion of fossil fuel energy. In addition, the higher economic could be used as a tool for structural transformation from non-renewables to renewables. This will not only provide economic prosperity, but also reduces environmental destructions in the long-run. Secondly, the energy efficiency related policies must be revised as improved level of energy efficiency significantly promote renewable energy consumption. In this sense, the G7 economies should improve energy efficiency in terms of promoting the energy saving products and services. In addition, the imposition of environmental related taxes on sectors that are excessively using non-renewable energy sources could be affective in the under-discussion economies. Nonetheless, the nonrenewable energy resources extremely depend upon the extraction of natural resources that causes resources depletion and ultimately leads to environmental degradation. Yet the environmental related taxes will reduce the excessive use of such non-renewable energy resources. Furthermore, environmental related technological innovation could be developed in a sense by enhancing investment in this specific sector. The improves level of technology tends to reduce the excessive fossil fuel energy consumption and will promote renewable energy use. Moreover, the subsidization of sectors in the incorporation of renewable energy resources could help the industries to transform dependence from fossil fuel towards renewable energy. These policies will help the G7 and other developed economies to reduce dependency in the fossil fuel and promote renewables, which will lead these nations towards sustainable development without harming environmental quality.

Disclosure statement

No potential conflict of interest was reported by the authors.

Notes

1. See details on https://www.aa.com.tr/en/politics/g7-countries-well-placed-to-fully-decarbonize-power-supply-by-2035-iea/2397751
2. For economic growth, see Li et al. (2021) and Anser et al. (2022), for energy efficiency see Wang et al. (2020), fir environmental related technological innovation, see Shahzad et al. (2021), and for environmental related taxes, see He et al. (2019a).
3. Visit: https://www.statista.com/chart/14175/fossil-fuel-phase-out_-g7-countries-have-work-to-do/

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