The Effect of Renewable Energy Consumption on Economic Growth: Evidence from the Renewable Energy Country Attractive Index

Shahbaz, Muhammad and Raghutla, Chandrashekar and Chittedi, Krishna Reddy and Jiao, Zhilun and Vo, Xuan Vinh

Beijing Institute of Technology, Beijing, China, GITAM University, Hyderabad, India, University of Hyderabad, Telangana, India, Nankai University, Tianjin, China, University of Economics Ho Chi Minh City, Vietnam

3 June 2020

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Muhammad Shahbaz [1, 2, 3]
[1]School of Management and Economics
Beijing Institute of Technology, Beijing, China.
[2] Institute of Business Research
University of Economics Ho Chi Minh City, Vietnam
[3] Department of Economics
COMSATS University of Islamabad
Lahore Campus, Pakistan.
Email: muhdshahbaz77@gmail.com

Chandrashekar Raghutla
Department of Economics,
GITAM School of Humanities and Social Sciences,
GITAM University, Hyderabad, India.
Email: chandrashekareco@gmail.com

Krishna Reddy Chittedi
School of Economics. University of Hyderabad,
Telangana, India. Email: krc@uohyd.ac.in

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

Xuan Vinh Vo
Institute of Business Research and CFVG
University of Economics Ho Chi Minh City, Vietnam
Email: vxvinh@yahoo.com

Abstract: The use of non-renewable resources emits a high quantity of CO_2 into environment, leading to a greenhouse effect, to reduce CO_2 emissions all countries have shifted to use renewable energy sources. Therefore, this study re-examines the effect of renewable energy consumption on economic growth across 38 renewable-energy-consuming countries from 1990 to 2018. The dynamic ordinary least squares (DOLS), fully modified ordinary least squares (FMOLS) and heterogeneous non-causality approaches are applied. The empirical analysis confirms the presence of a long-run relationship between renewable energy consumption and economic growth. Further, we noted that renewable energy, non-renewable energy, capital and labor have positive impact on economic growth, particularly, renewable energy consumption has a positive impact on economic growth for 58% of the sample countries. The empirical results suggest that international cooperation agencies, energy organizers, governments, and associated bodies must act together in increasing renewable energy investment for low carbon growth in most of these economies.
Keywords: Renewable Energy, Economic Growth, Renewable Energy Country Attractiveness Index

1. Introduction

Numerous studies have shown that the use of traditional fossil fuels (e.g., coal, natural gas, oil) lead to economic growth. However, the excessive utilization of non-renewable resources emits a high quantity of CO_2 into environment, leading to a greenhouse effect. Global CO_2 emissions increased from 25,688 million (MT) to 32,310 million (MT) for 2003-2012 period [1]. As stated by the World Resource Institute (WRI), over one-third of global greenhouse gas emissions are generated by traditional energy sources. Similarly, Hamit-Haggar [2] highlighted that greenhouse gas emissions assessment had become a significant part of international climate policy agenda. Currently, a nation must have renewable energy sources (e.g. hydro, geothermal, wind, solar, wave, tidal, and biomass), and these alternatives must have sustainable and non-polluting growth. The reduction of global greenhouse gas emissions has become the main global objective for a sustainable environment. Owing to increasing CO_2 emissions and energy consumption, environmental economists and policy analysts shifted their attention toward the use of renewable energy rather than traditional energy consumption. Recently, many international groups have begun to pressure emerging, developing, and developed nations to reduce carbon emissions. The path to sustainable environment must lead to decrease the use of traditional energy sources and emissions in power generation. Therefore, environmental pressures, technology, and deregulated energy markets can all play a major role in achieving a sustainable environment path.

In 2013, all renewables accounted for an estimated 19.1% of global final energy consumption[1]. According to a recent scenario, the growth of electricity sector is led by renewable energy sector; namely, solar PV, hydropower, and wind, while renewable energy consumption increases every year by 3.0% [3]. The share of natural gas (15.1%), coal (11.5%), and oil (39.9%) increased in 2013 [4]. At this point, environmental economists and

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[1]http://www.ren21.net/wp-content/uploads/2015/06/GSR2015_KeyFindings_lowres.pdf

policymakers need to focus on increasing the share of renewable energy to substitute traditional energy consumption; moreover, it is a major solution tool for sustainable economic growth. Renewable energy technology (sources e.g. hydro, geothermal, wind, solar, wave, tidal, and biomass), has generated energy which is used by industrial (production purpose) and household (daily uses). In this way, energy technology not only affects consumption-side but also affects production-side which in resulting, affects domestic production. On other hand, heavy energy is requiring in the process of production whose aim is producing sufficient renewable energy to fulfill demand for the process of production. In doing so, renewable energy (renewable technology) increases economic growth. Against this background, the IEA built an optimistic scenario; renewable energy share of electricity production will increase by 39% in 2050 (in 2002, production was at 18.3%). Thus, reducing worldwide CO_2 emissions by 50% will reduce global temperature by 2050. Therefore, renewable energy production will have an important role in maintaining global temperature between 2.0 and 2.4^{o}C [5].

In recent years, renewable energy growth has been encouraged by government-supported projects such as tax reductions and grants. Energy production costs have been reduced due to cost-competitiveness. In several countries, the production of renewable energy has broadly competed with traditional (conventional) energy sources. The production of renewable energy initiatives has been initiated in many nations; namely, the United States, Africa, Europe, Latin America, and Asia. This initiative has created installers of renewable energy technologies and emerging manufacturers. For example, in 2007, according to the Renewable Energy Policy Network for the 21st Century (REN21), improving the production of renewable energy capacity, research & development (R&D), and manufacturing plants cost more than $100 billion, a maximum ($71 billion) of which went into new renewable energy capacities (wind power and solar PV).

Recently, several studies in the energy literature have explored the relationship between energy consumption and economic growth. For instance: Masih and Masih (1996) for six Asian economies, Cheng (1999) for India, Apergis and Payne (2009) for Commonwealth of Independent States, Ozturk et al. (2010) for low- and middle-income countries, Ouedraogo (2013) for West African States, Aslan et al. (2014) for US, Huang et al. (2008) for 82 countries, Narayan et al. (2010) for 93 countries, Kasman and Duman (2015) for EU countries, Costantini and Martini (2010) for 71 countries, Belke et al. (2011) for 25 OECD countries, Coers and Sanders (2013) for 30 OECD countries, Wolde-Rufael (2009) for African countries, Kahsai et al. (2012) for Sub-Saharan Africa, Śmiech and Papież (2014) for EU countries, Jafari et al. (2012) for Indonesia, Dogan (2014) for Kenya, Benin, Congo and Zimbabwe, Nasreen and Anwar (2014) for 15 Asian countries, Doganet al. (2016) for Turkey and, Fang and Chang (2016) for Asia Pacific region (16 countries). However, studies on the consumption of renewable energy and economic growth are still limited. The growing sources of renewable energy have significantly attracted energy policy analysts and academics. The study provides several important contributions and highlights its relevance to existing literature on renewable energy-economic growth nexus. First, a study by Bhattacharya et al. [5] studied the impact of the consumption of renewable energy on economic growth during the 1991-2012 period by applying several panel econometric techniques such as cross-sectional dependence, Pedroni panel cointegration, fully modified ordinary least squares (FMOLS), dynamic ordinary least squares (DOLS), and heterogenous panel causality. Their empirical results showed that renewable energy consumption has a positive impact on economic growth; meanwhile, the causality connects non-renewable energy consumption to economic growth. Therefore, this study re-examines renewable energy consumption-economic growth nexus with new data sets.

Second, the majority of country-selection in existing energy literature is purpose-based. For instance, such studies employed renewable energy consumption that covered consumers and ignored the particular role of producers. To solve this issue, we employed the Renewable Energy Country Attractiveness Index (RECAI) (developed by Ernst and Young Global Limited) for country-selection, which provided also provides a renewable energy indicator. RECAI is based on three energy-factors (energy-specific, macroeconomic, and technology factors), which shows that RECAI covers not only energy market but also economic stability and production technology. This study focuses on RECAI which is developed based on three main factors such as macroeconomics, technology, energy-specific. Based on these factors, they developed Renewable Energy Country Attractiveness Index (RECAI). Globally, they estimated their economic strength following three factors and based on these factors, they gave ranking in the globe. It encourages us to re-examine the relationship between renewable energy consumption and economic growth of 38 countries due to data availability[2].

Third, we have included traditional inputs in production function; that is, capital and labor. Non-renewable energy and the consumption of renewable energy are also considered as important determinants of production due to their relative effect on growth process. Consequently, if non-renewable energy use has much impact, global warming could soon be reduced by 25% [6] and vice versa. Forth, long-run output elasticities for panel and individual

[2]Our study country selection for panel is not random. It is based that Renewable Energy Country Attractiveness Index (RECAI) developed by Ernst and Young Global Limited. RECAI has a particular methodology and the ranking is based on macroeconomic drivers (macro stability and investor climate), technology specific drivers (project attractiveness), and energy-specific factors for each market (Prioritization of renewables and Bankability of renewables). All the above parameters are covers up-to 10 different types of data. Such 10 different types of datasets generating the score and calculate parameter scores based on their weighted values. Based on this, Renewable Energy Country Attractiveness Index (RECAI) score and ranking, weighted values are important in the analysis of all the datasets, development decision as well as limitation of driving investment. All the technologies are selected a weighting based projected investments and it's based on share of historical. The 10 different datasets are including both the purchased data or publicly available data and adjustments to third-party data. The technology-specific rankings produce based on their weighted average score, it including the energy market, macroeconomic drivers and technology-specific parameters however, some of the markets may be significantly attractive in particularly some specific technologies while also face other major problems to entry.

countries are also estimated by considering cross-sectional and time-dimensions of the panel. This panel analysis has significant power as compared to time-series approaches. The empirical analysis is very useful for policy decisions because, in the process of economic growth, it indicates long-term demand for renewable (non-renewable) energy sources. In doing so, we applied cross-sectional dependence, Pedroni cointegration, heterogeneous panel causality, and both FMOLS and DOLS techniques. For example, traditional unit root tests are ineffective when applied to a series with cross-sectional dependence due to lower power. These first-generation unit root tests seem to over-reject the null hypothesis of cross-sectional dependency when defining the order of integration of variables is within the panel. In doing so, we have applied cross-sectional augmented IPS (CIPS) test. Pedroni cointegration test is based on the two-step long-run equilibrium cointegration method of Engle-Granger causality. This test developed seven test statistics: pooling (panel statistics test or within-dimension) which are allows homogeneity of the AR term and (group statistics test or between-dimension) are assumes heterogeneity of the AR term. These seven test statistics provide empirically efficient and reliable empirical results. Similarly, DOLS and FMOLS approaches provide very similar signs and significant results for each variable, but they slightly vary in magnitude. The reason is that both approaches indicate the endogeneity and serial correlation, model may have. Lastly, Dumitrescu and Hurlin [7] non-causality test is applied for examining causality between the variables, which supports the presence of heterogeneity, and works under the fixed coefficients in a VAR framework. Therefore, Dumitrescu and Hurlin [7] methodological technique appears to be more reliable than that of conventional Granger causality tests.

Fifth, previous energy literature has demonstrated a relationship between the consumption of renewable energy and economic growth via panel data with different countries. These panel data sets are essentially heterogeneous [5], which is the main criticism.

Moreover, empirical results by traditional causality are ambiguous. Thus, we apply heterogeneous panel non-causality estimation technique developed by Dumitrescu and Hurlin F [7] to examine the causal association between consumption of renewable energy and economic growth. The empirical results validated the presence of a long-run relationship between the consumption of renewable energy and economic growth. Moreover, renewable energy consumption increases economic growth for 58% of the selected countries. There is also the feedback effect between the consumption of renewable energy and economic growth.

The present study examines the relationship between renewable energy consumption and economic growth by using updated data set 1990-2018 for 38 countries: Australia, Austria, Belgium, Brazil, Bulgaria, Canada, Chile, China, the Czech Republic, Denmark, Finland, France, Germany, Greece, India, Ireland, Israel, Italy, Japan, Kenya, Republic of Korea, Mexico, Morocco, the Netherlands, Norway, Peru, Poland, Portugal, Romania, South Africa, Spain, Sweden, Thailand, Turkey, Ukraine, the United Kingdom, and the United States. Previous studies have shown positive relationship between renewable energy consumption and economic growth. Therefore, our study also looked into whether those countries are constantly encouraging renewable energy consumption by increasing capital. Interestingly, our study found that only 22 countries have shown positive relationship between renewable energy consumption and economic growth. The study by Bhattacharya et al. (2016) also examined same countries, same methodology with same variables. Their results reported that renewable energy consumption has a positive impact on economic growth for 23 countries. Our study confirmed that renewable energy consumption has a negative impact on economic growth in 9 countries while Bhattacharya et al. (2016) established negative impact only for 4 countries. This implies that those nations need to increase capital for sustainable development of renewable energy consumption.

2. Literature Review

In the existing energy literature, the relationship between the consumption of renewable energy and economic growth has significant attracted environmental economists and policymakers worldwide. Therefore, many studies have explored this relationship by employing three different types of datasets: time-series, panel, and cross-country analyses. Nevertheless, the empirical results of previous studies are mixed across countries and can be explained in four hypotheses. First, an increase in the consumption of renewable energy promotes a positive output, and if any reduction in renewable energy consumption occurs, then energy conservation policies will have a significant and negative impact on economic growth. It implies that the consumption of renewable energy causes economic growth, which is called the *growth hypothesis*. Second, the *conservation hypothesis* implies that unidirectional causality relationship which, connect economic growth to the consumption of renewable energy exits; thus, a decline or increase in consumption of energy is not going to affect economic growth. Third, the *feedback hypothesis* suggests a bidirectional causality relationship between the consumption of renewable energy and economic growth. Any rise in the use of renewable energy would play an important role in stimulating economic growth with a reverse effect. Fourth, the *neutrality hypothesis* shows that these two variables are independent. The majority of the existing energy literature studied the linkages between renewable energy use and economic growth but produced mixed empirical results across countries. For example, Sadorsky [8] report that empirical results showed that increasing per capita income increases renewable energy consumption for 18 emerging countries. His empirical findings further reported that a 1% increase in per capita income increases renewable energy consumption by 3.5%. Similar result is established by Tiwari [9] for India. Further, Inglesi-Lotz [10] also document that consumption of renewable energy has a substantial and positive impact on economic growth. A recent study by Rafindadi and Ozturk

[11] showed that a 1% increase in the consumption of renewable energy increases economic growth by 0.219%. They noted the presence of a feedback effect between economic growth and consumption of renewable energy. Bhattacharya et al. [12] highlighted that the use of renewable energy has a stimulating impact on economic growth for the case of 85 countries. Recently, Kutan et al. [13] found that the consumption of renewable energy has a positive and considerable impact on economic growth for major emerging market economies. They found a neutral effect between the consumption of renewable energy and economic growth, which was confirmed by the Dumitrescu and Hurlin [7] panel causality approach. Similar results are established by Paramati, Apergis, and Ummalla [14] in the case of G20 economies.

By contrast, Bilgili and Özturk [15] reported that consumption of biomass energy has a considerable and positive impact on economic growth in a panel of G7 countries. Similarly, Ozturk and Bilgili [16] reported that renewable (biomass) energy consumption increases economic growth for 51 Sub-Saharan Africa nations. Regarding the 1990-2009 period, Alper and Oguz [17] documented that the consumption of renewable energy has a considerable positive impact on economic growth for European Union (EU). Ito [18] showed that the consumption of renewable energy is the main determinant of economic growth for 42 developed economies. David [19] found a positive effect of renewable energy on economic growth in 22 OECD nations. Apergis and Payne [20] documented that consumption of renewable energy has a positive and significant impact on economic growth. Therefore, their statistical results further confirmed the existence of bidirectional causality between the consumption of renewable energy and economic growth in the case of 20 OECD nations. Similar results are also established by Ohler and Fetters [21], in the case of 20 OECD countries, and Apergis and Payne [22], in the case of 6 American economies.

Apergis and Payne [23] indicated the presence of the feedback effect between the consumption of renewable energy and economic growth for 13 countries. In the case of 80 countries, Apergis and Payne [24] found that consumption of renewable energy (consumption of non-renewable energy) and economic growth are interdependent, which is a feedback effect. Salim and Rafiq [25] also reported that consumption of renewable energy causes economic growth, and in return, economic growth causes consumption of renewable energy in six emerging countries: Indonesia, Turkey, Philippines, India, China, and Brazil. Similarly, Koçak and Şarkgüneşi [26] noted the existence of the feedback effect between renewable energy consumption and economic growth in the case of nine Black Sea and Balkan economies, which was confirmed by Dumitrescu and Hurlin's [7] heterogeneous causality. Moreover, Lin and Moubarak [27] reported a bidirectional causality relationship between renewable energy consumption and economic growth for the Chinese economy. Shahbaz et al. [28] found the presence of a bidirectional causality relationship between economic growth and consumption of renewable energy in Pakistan. Tugcu et al. [29] confirmed that consumption of renewable energy and economic growth are complementary, but the relationship between two variables is different from country to country and differs with specifications in G7 countries. Al-mulali et al. [31] showed the existence of the feedback effect between the variables for 79% of nations, the conservation hypothesis for 2% of the nations, and the neutrality hypothesis for 19% of the nations between renewable energy consumption and economic growth in 108 nations; namely, low-income, lower-middle-income, upper-middle-income, and high-income countries. Cho et al. [32] confirmed the presence of a bidirectional causality relationship between renewable energy consumption and economic growth for developing countries. Moreover, renewable energy consumption leads to economic growth in developed countries. Further, Sebri and Ben-Salha [33] reported the presence of the feedback effect between the variables in the case of BRICS (Brazil, Russia, India, China, and South Africa) countries. In the case of the 80 developing and developed economies, Apergis and Danuletiu [34] stated that the consumption of renewable energy and GDP are complementary.

In the case of China, Fang [35] reported that a 1% increase in the consumption of renewable energy increases GDP per capita by 0.162% and real GDP by 0.120%. He also documented unidirectional causality from renewable energy consumption to economic growth; that is, the growth hypothesis for the Chinese economy. Further, Omri et al. [36] highlighted that renewable energy consumption causes economic growth in the case of India, Netherlands, Japan, Sweden, and Hungary. Similar results are confirmed by Ohlan [37] in the case of India from 1971 to 2012. In the case of Tunisia, Brini et al. [38] documented the existence of growth hypothesis. On the contrary, Dogan [39] indicated that economic growth causes consumption of renewable energy, confirming the presence of the conservation hypothesis in Turkey. Menegaki [40] confirm the presence of the *neutral effect* between the variables; that is, renewable energy consumption and economic growth are independent in a panel of 27 European countries for the 1997-2007 period. Ocal and Aslan [41] highlighted that consumption of renewable energy has a negative but significant impact on economic growth, and renewable energy consumption causes economic growth for the Turkish economy. Bhattacharya et al. [5] showed the presence of the neutral effect between the variables for 38 (RECAI) economies during the 1991-2012 period. Maji and Sulaiman [42] confirmed that the use of renewable energy consumption reduces economic growth by lowering productivity. They also suggested that countries should adopt renewable energy techniques to minimize the adverse effect. Zhou and Li [43] confirmed the presence of the Environmental Kuznets curve (EKC) and growth hypothesis for 33 nations from 1990 to 2016. Can and Korkmaz [44] reported the validation of bidirectional causality between renewable electricity output, as well as renewable energy consumption and economic growth in the case of Bulgaria during the period of 1990-2016. Lee and Jung [45] reported that renewable energy consumption has a significant but negative impact on economic growth. They also found a unidirectional causality from economic growth to renewable energy consumption in South Korea, spanning the 1990-2012 period. Fotourehchi [46] showed that the consumption of renewable energy has a positive and considerable impact on economic growth and established a unidirectional causality from renewable energy consumption to economic growth in the case of 42 developing countries. Anwar et al. [47] found that renewable energy consumption has a positive and significant impact on economic growth. Their analysis also noted that the use of renewable energy causes economic growth for 29 Organization of Islamic Cooperation (OIC) nations. Marinas et al. [48] showed that renewable energy consumption increases economic growth; they also found a bidirectional causality relationship between renewable energy consumption and economic growth in a panel of EU member countries from 1990 to 2014. Ntanos et al. [49] showed that the consumption of renewable energy increases economic growth in a panel of 25 European economies from 2007 to 2016. Using 151 developed and developing countries data, Alvarado et al. [78] reported the presence of U-shaped association between economic growth and carbon emissions. Additionally, urbanization, manufacturing and energy consumption add to environmental degradation. Using Pakistani data, Khan et al. [79] found that economic growth and energy consumption are main determinants of carbon emissions. Lin and Raza [80] applied a trans-log production function and noted that capital and energy technologies are beneficial for economic growth. Aydin [81] indicate the presence of feedback effect between electricity (non-renewable) consumption and economic growth. Shao et al. [82] found that capital, labor and water add to industrial output and but decline in energy consumption lowers output growth in China, for the period of 2004-2014. Yi et al. [83] reported that technological progress is positively linked with haze pollution reduction for

China. Rahman and Velayutham [84] noted that renewable and non-renewable energy consumption add to economic growth in Asian countries and causality is running from economic growth to renewable energy consumption.

In the energy literature, there are few studies have addressed the problem of cross-sectionally dependence and degree of heterogeneity. Therefore, to address this problem our study applied heterogeneous panel technique with cross-sectional dependence. Moreover, energy policies developed at the global level can also affect individual nations. Furthermore, it also handles exogenous shock. This is one of the studies dealing with mentioned issues by applying heterogeneous panel techniques for selected countries.

Table-1: A Summary of the Literature on Renewable Energy Consumption-Economic Growth Nexus

Author(s)	Period	Methodology	Countries	Findings
Panel Studies for Panels				
Sadorsky [8]	1994-2003	Panel	18 Emerging economies	GDP→RE
Apergis and Payne [23]	1992-2007	Panel	13 Eurasian countries	RE↔GDP
Apergis and Payne [20]	1985-2005	Panel	20 OECD countries	RE↔GDP
Apergis and Payne [22]	1980-2006	Panel	6 Central American countries	RE↔GDP
Menegaki [40]	1997-2007	Panel	27 European countries	RE≠GDP
Apergis and Payne [24]	1990-2007	Panel	80 countries	RE↔GDP
Salim and Rafiq [25]	1980-2006	Panel	6 major emerging countries	RE↔GDP in the short-run
Marques and Fuinhas [50]	1990-2007	Panel	24 European countries	RE≠GDP
Tugcu et al. [29]	1980-2009	ARDL	G7 countries	The relationship is different for countries and varies with specification
Al-mulali et al. [31]	1980-2009	FMOLS	108 countries	79% feedback; 2% conservation; 19% neutrality
Sebri and Ben-Salha [33]	1971-2010	VECM	BRICS	RE↔GDP in the short-run
Bilgili and Özturk [15]	1980-2009	Panel	G7 countries	Biomass has a positive impact on GDP
Ozturk and Bilgili [16]	1980-2009	Panel	51 Sub-Sahara African countries	Biomass has a positive impact on GDP
Cho et al. [32]	1990-2010	Panel, VECM	31 OECD and 49 non-OECD countries	RE↔GDP for less developed and GDP→RE for developed
Fotourehchi [46]	1990-2012	Panel	42 developing countries	RE has a positive

				impact on economic growth and RE→GDP
Anwar et al. [47]	1990-2014	Panel	29 countries	RE has a positive impact on economic growth and RE→GDP
Marinas et al. [48]	1990-2014	Panel	European Union	RE↔GDP
Ntanos et al. [49]	2007-2016	Panel	25 European countries	RE has a positive impact on economic growth
Maji and Sulaiman [42]	1995-2014	DOLS	15 West Africa	Renewable energy consumption reduces economic growth
Zhou and Li [43]	1990-2016	quantile regression	33 countries	EKC and growth hypothesis

Time Series Studies for Individual Countries

Author(s)	Period	Methodology	Countries	Findings
Menyah and Rufael [51]	1960-2007	Granger Causality	US	GDP→RE
Tiwari [9]	1960-2009	Structural VAR	India	RE→GDP
Fang [35]	1978-2008	OLS	China	RE→GDP
Yildirim, Saraç, and Aslan [52]	1960-2010	Toda-Yamamoto causality	US	RE→GDP
Ocal and Aslan [41]	1990-2010	Toda-Yamamoto causality	Turkey	GDP→RE
Pao and Fu [53]	1980-2009	Cointegration, ECM	Brazil	RE↔GDP
Lin and Moubarak [27]	1977-2011	ARDL	China	RE↔GDP
Chang et al. [54]	1990-2011	Granger Causality	G7	GDP≠RE for Canada, GDP→RE for France& UK RE→GDP for Germany
Shahbaz et al. [28]	1972-2011	ARDL	Pakistan	RE↔GDP
Pao and Fu [55]	1980-2011	Lotka-Voterra model	Mexico	GDP≠RE
Bloch et al. [56]	1977-2013	Cointegration	China	RE→GDP
Mbarek, Saidi, and Amamri [57]	2001:1-2012:3	Granger Causality	France	GDP→RE
Lee and Jung [45]	1990-2012	ARDL	South Korea	RE has a negative impact on economic growth and GDP→RE
Can and Korkmaz [44]	1990-2016	ARDL	Bulgaria	RE↔GDP
Haseeb et al. [58]	1980-2016	ARDL	Malaysia	RE has a positive impact on economic growth

Notes: →, ↔, and ≠ indicate a unidirectional causality, bidirectional causality, and no causality, respectively[3].

[3] Omri [85] reported that in energy-growth nexus: 29% (21%) confirms the presence of the growth hypothesis (neutrality hypothesis), 23% (27%) supports the conservation hypothesis (feedback hypothesis).

Globally, many nations have encouraged the development of renewable energy programs by providing different incentives like tax credits, subsidies. These countries have also been offering other incentives for encouraging renewable energy consumption, which has made renewable energy sources more cost-competitive. Renewable energies are largely competitive with traditional energy sources in many countries. Along with the United States and European countries, renewable energy programs have emerged in Africa, Latin America and Asian countries. Furthermore, it has also provided advanced renewable energy technologies and leading manufacturers outside the United States and European countries.

3. Renewable Energy Resources Overview in Sampled Countries

Natural processes that produce renewable energy is either unlimited or can be refilled. There are a few types of renewable energy sources, such as hydropower, wind, bioenergy, ocean energy, and solar. The percentage of renewable energy has developed considerably in areas such as heating, electricity, transport sectors, and cooling. According to REN21, China led international renewable energy and fuel investments, followed by the US, Japan, India, and Australia. The Chinese government also played a leading role in hydropower, solar water heating, and solar photovoltaic (PV). The study reported that the top five countries are Iceland, Denmark, Germany, Sweden, and Finland, based on renewable energy capacity per capita. These positions are based on various energy efficiency sources per capita[4]:

- Hydropower energy production: China, Canada, Brazil, US, Russian Federation
- Solar PV energy production: Germany, Australia, Japan, Belgium, and Italy
- Wind power energy production: Denmark, Iceland, Germany, Sweden, and Portugal
- Geothermal energy production: China, Turkey, Iceland, Japan and Hungary

[4]For detail, see page 25, REN21 Renewables 2019 Global Status Report: https://www.ren21.net/wp-content/uploads/2019/05/gsr_2019_full_report_en.pdf

In contrast, renewable energy sources reached 35% of growth in non-OECD economies, while, for OECD economies, renewable energy accounted for 80% of new generation. Similarly, developing and emerging nations are investing in renewable energy more rapidly [4]. Global renewable energy expenditures rose from $120.9 billion to $136.1 billion for developed nations and $30.5 billion to $61.6 billion for developing countries. It increased from $177 billion to $289 billion globally from 2008 to 2018. The significant statistics are also reported below (see REN21):[5]

- China had the largest investment of $92.2 billion in renewable energy in 2018; the second in Europe was $61.2 billion, and the third in the US was $48.5 billion.
- Investment in emerging and developing nations increased to $131.3 billion compared to the year before and, for developed countries, increased to 11 percent at $136.1 billion. Moreover, Japan ($18.3 billion), India ($15.4 billion), Australia ($9.5 billion), Spain ($7.5 billion), the Netherlands ($5.1 billion), Sweden ($4.6 billion), France ($4.5 billion), South Africa ($3.9 billion), Mexico ($3.7 billion), and Brazil ($3.3 billion) were ranked in the top ten investing nations. Countries that invested more than $1 billion include Denmark, Belgium, Morocco, Canada, the United Kingdom, and Chile.
- The contribution of all individual renewable energy sources includes wind (5.5%), solar PV (2.4%), biomass energy and waste-to-power energy (2.2%), geothermal energy (0.4%), and hydropower (15.8%), respectively. All these renewables contribute an estimate of 26.2% of global electricity production in 2018 as compared to 26.5% in 2017.
- In 2018, international market renewable energy investment was increased in solar and wind energy. Investment in solar energy increased from $145.4 billion to $180.2 billion

[5] For detail, see page 148, REN21 Renewables 2019 Global Status Report: https://www.ren21.net/wp-content/uploads/2019/05/gsr_2019_full_report_en.pdf

from 2016 to 2017, while wind energy investment increased from \$126.3 billion in 2016 to \$130.9 billion in 2017.

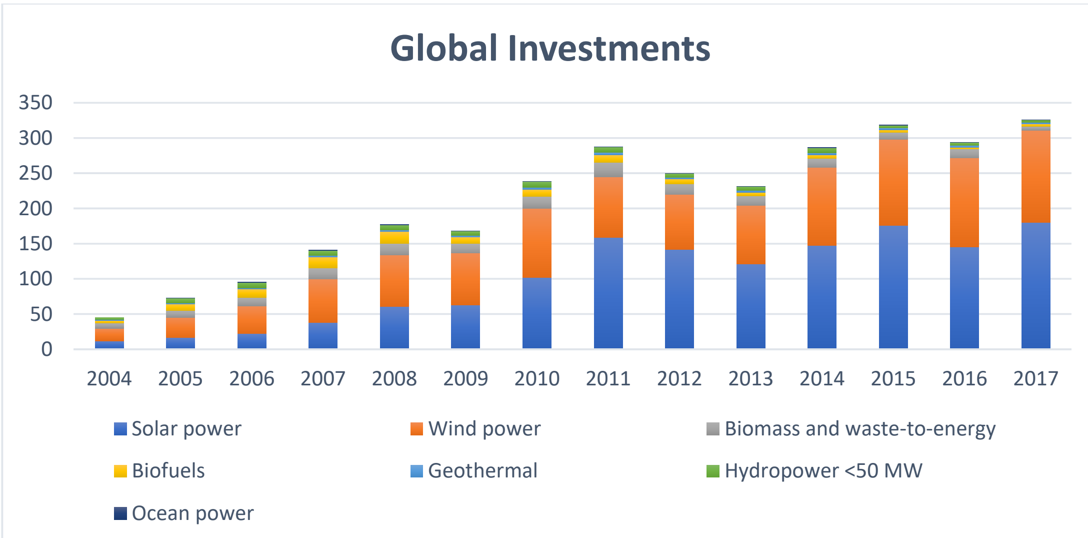

Figure-1: Global Investments in Renewable Energy 2004–2017
Source: REN21 Renewables 2019

4. Empirical Model and Data Collection

This study re-examines the linkages between renewable (non-renewable) energy consumption and economic growth. We, therefore, have used an augmented neoclassical production function following Bhattacharya et al. [5] and Kocak and Şarkgüneşi [26]. This augmented production role considers the use of renewable (non-renewable) resources along with capital and labor. The general type of augmented production function that considers renewable (non-renewable) energy consumption, capital, and labor as individual inputs is modeled as follows:

$$Y_{it} = f(RE_{it}, NRE_{it}, K_{it}, L_{it}), \quad (1)$$

Where i and t stand for nation and time, respectively. $Y_{it}, RE_{it}, NRE_{it}, K_{it}$ *and* L_{it} indicate economic growth, consumption of renewable energy, non-renewable energy use, capital, and labor[6]. Thus, equation-1 can be parameterized as follows:

$$Y_{it} = RE_{it}^{\beta 1i} NRE_{it}^{\beta 2i} K_{it}^{\beta 3i} L_{it}^{\beta 4i} . \quad (2)$$

The transformation of the variables into a natural logarithm provides efficient and consistent empirical results [28]. Furthermore, Ummalla and Raghutla [59] and Raghutla et al. [60] [61], Raghutla [86] and Shahbaz et al. [87] also suggested the use of a log-linear transformation for reliable empirical analysis. The log-linear conversion of the dataset is a more general approach, and all coefficients in the regression are interpreted as elasticities.[7] The empirical equation of augmented production function is modeled as follows:

$$\ln Y_{it} = \beta_{1i} \ln RE_{it} + \beta_{2i} \ln NRE_{it} + \beta_{3i} \ln K_{it} + \beta_{4i} \ln L_{it} + \varphi_{it} , \quad (3)$$

where $\beta_{1i}, \beta_{2i}, \beta_{3i}$ *and* β_{4i} are elasticities of economic growth (measured by real GDP per capita) regarding the consumption of renewable energy, non-renewable energy use, and capital measures by real gross fixed capital formation per capita (K) and labor (L), respectively. φ is the error term.

This study uses an unbalanced panel of 38 nations based on RECAI. The index is developed for 40 nations. However, we have selected 38 nations[8]. The data for GDP (2010

[6]Our sample variables are different in units, it is considered to normalize the sample data series before beginning the empirical analysis.
[7]Following studies like Apergis and Payne [20] [23], we use log-linear model.
[8]Australia, Austria, Belgium, Brazil, Bulgaria, Canada, Chile, China, the Czech Republic, Denmark, Finland, France, Germany, Greece, India, Ireland, Israel, Italy, Japan, Kenya, Republic of Korea, Mexico, Morocco, the Netherlands, Norway, Peru, Poland, Portugal, Romania, South Africa, Spain, Sweden, Thailand, Turkey,

constant US dollars)[9], gross fixed capital formation (2010 constant US dollars), and total labor force is collected from the World Development Indicators (WDI)[10]. We probed WDI to attain data for renewable energy use and non-renewable energy use (kg of oil equivalent per capita). The total population is a proxy for the transformation of all the variables into per capita units. The descriptive statistics are documented in Table-2, which demonstrates heterogeneity across nations. Figure-2 to 5 show the percentage of total final energy consumption of renewable energy sources for the 1990-2018 period.

Table-2: Average Annual Growth of all selected sample Countries (1990-2016) and Slovenia (1995-2016) (%)

Variable	Y	K	L	RE	NRE
Australia	3.811	3.599	3.797	3.956	3.732
Austria	3.771	3.602	3.762	4.080	3.774
Belgium	3.766	3.666	3.761	34.343	3.693
Brazil	3.789	3.354	3.816	3.559	3.948
Bulgaria	3.771	3.539	3.653	16.229	3.574
Canada	3.782	3.766	3.771	3.703	3.711
Chile	3.884	3.651	3.835	3.413	4.052
China	4.032	4.345	3.741	2.635	4.299
Czech Rep.	3.771	3.722	3.724	7.845	3.611
Denmark	3.764	3.732	3.716	6.559	3.625
Finland	3.764	3.361	3.709	4.333	3.731
France	3.754	3.626	3.735	4.105	3.685
Germany	3.754	3.477	3.726	13.116	3.636
Greece	3.733	2.872	3.741	5.066	3.715
India	3.921	3.820	3.788	3.268	4.072
Ireland	3.908	4.483	3.828	9.774	3.697
Israel	3.861	3.742	3.893	2.753	3.759
Italy	3.726	3.405	3.718	7.856	3.678
Japan	3.735	3.314	3.713	4.363	3.690

Ukraine, the United Kingdom, and the United States. Saudi Arabia (ranked 35) and Taiwan (ranked 24) are not included in empirical model due to the unavailability of data. The study spans the 1990-2018 period. For Slovenia, the study covers the 1995-2018 period.

[9] We agree that recently few studies used night time light intensity as proxy for economic growth. It has some disadvantages and concerns to use a proxy for GDP. There are two serious night-light data limitations that researchers have been grappling with for some time. One, satellites that records this data are not capable of specifically detecting artificial lights and recording only the lights emitted from vehicle traffic, rooftops, and streets. The second is more serious: data from night-lights does not differentiate between richer and wealthier regions. In the satellite images everything is dark above a threshold. Studies which are adopted night time light intensity data as a proxy for economic growth to estimate the level of economic activity in regions where economic data is erratic or unavailable. Hence, we believed that GDP is close proxy for economic growth.

[10] https://datacatalog.worldbank.org/dataset/world-development-indicators

Kenya	3.849	3.480	3.886	3.665	3.761
Korea, Rep.	3.881	3.458	3.785	7.712	4.139
Mexico	3.792	4.015	3.838	3.123	3.721
Morocco	3.851	3.873	3.808	3.048	4.086
Netherlands	3.775	3.513	3.767	35.359	3.691
Norway	3.790	3.826	3.768	3.677	3.7641
Peru	3.882	4.075	3.888	3.274	4.013
Poland	3.835	3.595	3.713	9.949	3.663
Portugal	3.751	3.086	3.725	3.778	3.810
Romania	3.774	3.883	3.634	9.724	3.459
Slovenia	4.643	4.143	4.564	5.718	4.573
South Africa	3.793	3.617	3.829	3.722	3.750
Spain	3.773	3.406	3.790	4.436	3.743
Sweden	3.780	3.497	3.728	4.137	3.664
Thailand	3.855	3.181	3.758	3.324	4.252
Turkey	3.859	3.997	3.802	2.923	3.974
Ukraine	3.631	3.208	3.666	-11.532	3.394
United Kingdom	3.772	3.311	3.735	-18.008	3.585
United States	3.781	3.641	3.751	5.616	3.658

Note: Growth rates are calculated using the original data.

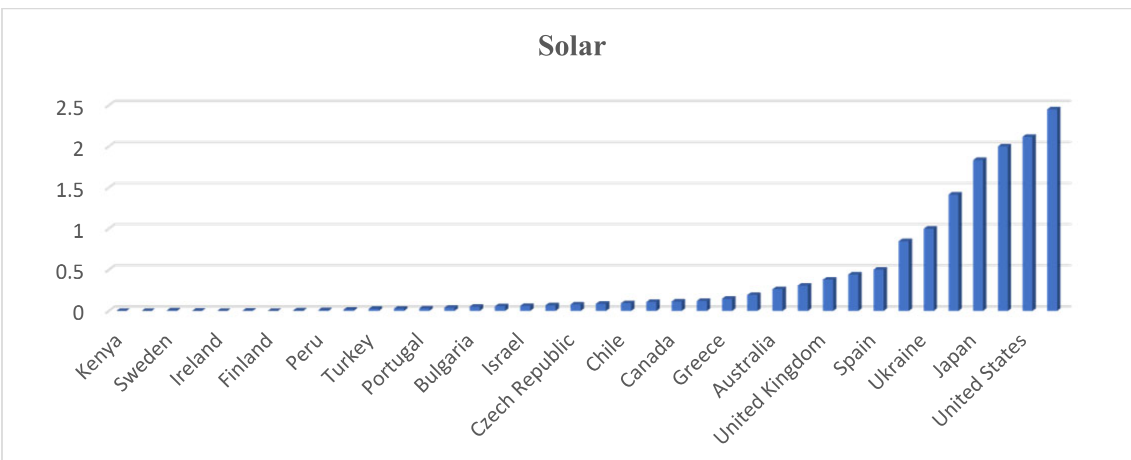

Figure-2: Percentage of Solar Energy in Total Energy Consumption
Source: WDI.

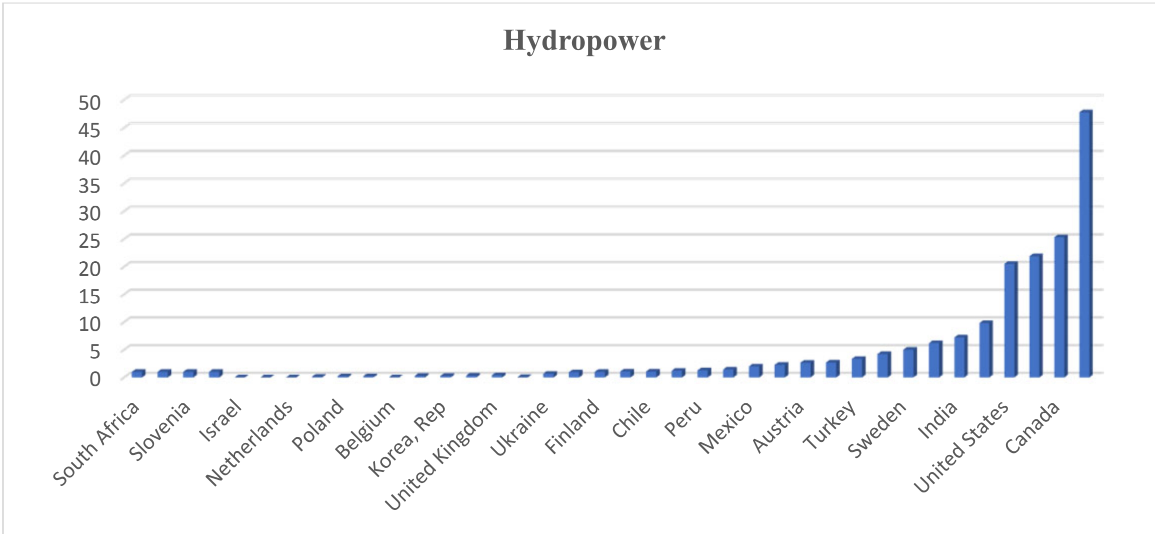

Figure-3: Percentage of Hydropower Energy in Total Energy Consumption
Source: WDI.

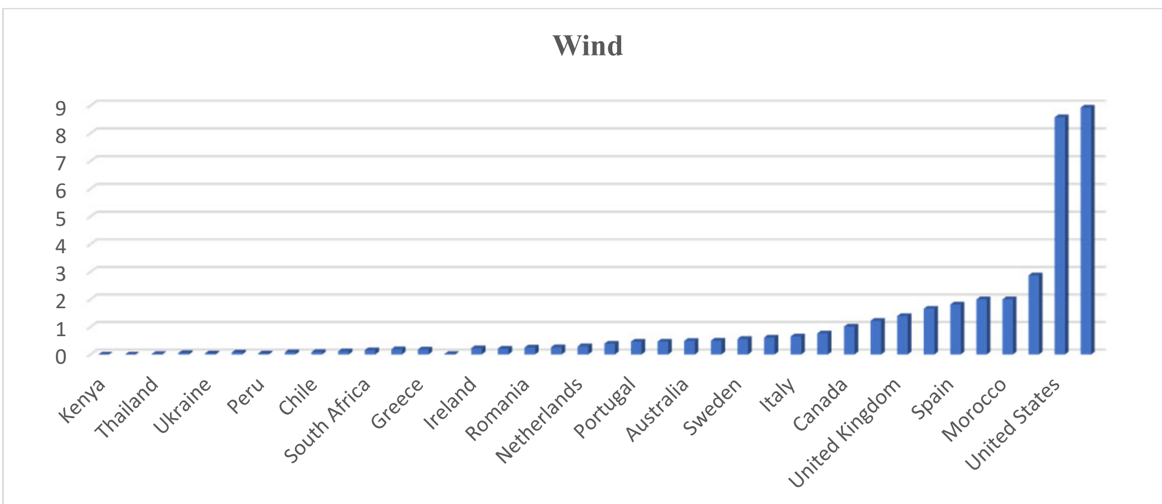

Figure-4: Percentage of Wind Energy in Total Energy Consumption
Source: WDI.

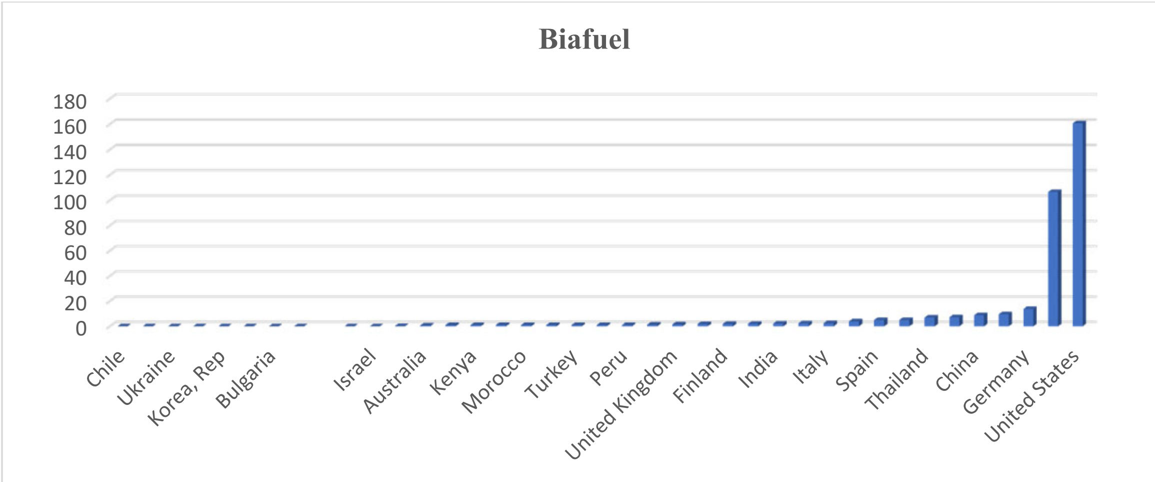

Figure-5: Percentage of Biofuel Energy in Total Energy Consumption
Source: WDI.

Figure-2 to 5 show the renewable energy mix; the use of solar energy was dominant as compared to hydropower, wind, and biofuel. A steady increase in wind and hydropower has already penetrated renewable energy locations as an integral part of the global energy mix. Growing biofuel demand reduces dependence on non-renewable energy imports, maintains low carbon emissions, and increases rural employment. The rapid expansion of consumption of renewable energy generation has resulted in lower generation costs.

5. Empirical Strategy

5.1 Cross-sectional Dependence Test and Unit Root Tests

We first examine the presence of cross-sectional dependence. Due to regional economic, trade, financial, energy, and environmental policies, cross-sectional dependence can exist. This study employs a cross-sectional dependence test developed by Pesaran [62]. To solve this issue, we use Pesaran's [63] cross-sectional augmented IPS (CIPS) test. Therefore, the empirical equation of CIPS unit root test is modeled as follows:

$$y_{it} = \alpha_i + \beta' X_{it} + u_{it}, \quad (4)$$

where Y_t is the variable in the time t; $i = 1,2\ldots\ldots N; t = 1,2\ldots\ldots T. X_{it}$ is a $K \times 1$ vector of regression, β is a $K \times 1$ parameter vector, and α_{it} indicates time-invariant individual nuisance parameters. Here, u_{it} is presumed that the null hypothesis is independent, and the alternative hypothesis u_{it} can be cross-sectional. However, no serial correlation is leftover.

$$H_0 : P_{ij} = P_{ji} = \text{cov}(u_{it}, u_{jt}) = 0 \quad \text{for} \quad i \neq j,$$

$$H_1 : P_{ij} = P_{ji} \neq 0 \quad \text{for the same} \quad i \neq j,$$

where p_{ij} is the product-moment correlation disturbance and is given by

$$p_{ij} = p_{ji} = \frac{\sum_{t=1}^{T} u_{it} u_{jt}}{\left(\sum_{t=1}^{T} u^2{}_{it}\right)\left(\sum_{t=1}^{T} u^2{}_{jt}\right)^{1/2}}, \tag{5}$$

where N increases with the number of possible pairings (u_{it}, u_{jt}).

5.2Pedroni Panel Cointegration Test

We use the Pedroni panel cointegration test to estimate the long-term cointegration relationship between the variables. This panel cointegration approach is developed by Pedroni [64] [65]. The empirical equation is modeled as follows:

$$y_{i,t} = \alpha_i + \beta_{1i} x_{1i,t} + \beta_{2i} x_{2i,t} + \ldots\ldots + \beta_{Mi} x_{Mi,t} + \varepsilon_{i,t}, \tag{6}$$

where t = 1, …., T; here*,* T is the number of observations in time, N applies to the panel's number of countries, and M is the number of independent parameters. $\beta_{1i,\ldots\ldots}, \beta_{Mi,}$ are the slope coefficients. α_i is the number of specific intercepts across each cross-section.

5.3 Fully Modified OLS and Dynamic OLD Tests

The long-run elasticity of output is calculated using both Pedroni's [66] [67] FMOLS and DOLS method[11]. The equation is modeled as follows:

$$Y_{it} = \delta_i + \beta_i X_{it} + \varepsilon_{it}, \tag{7}$$

where Y and X indicate economic output and the corresponding vector of independent variables, while i, t, and ε stands for individuals, time, and the error term.

$$Y_{it} = \vartheta_i + x'_{it}\mu + \sum_{j=-p}^{p} \sigma_{ik} \Delta x_{it+p} + e_{it}, \tag{8}$$

where *Y, X, i, t,* and *e* represents economic output, the corresponding vector of independent variables, individual countries, time, and the error term.

5.5 Panel Causality Test

We use a model that supports cross-sectional heterogeneity to explore the causality of the short-run dynamic bivariate panel between variables. Dumitrescu and Hurlin [7] suggest a simple approach to testing the null hypothesis of homogeneous non-causality against the alternative hypothesis of heterogeneous non-causality. The Dumitrescu and Hurlin (2012) non-causality test supports the presence of heterogeneity and works under the fixed coefficients in a VAR framework. However, the main advantage of Dumitrescu and Hurlin (2012) non-causality test is that it assumes that all the coefficients are different across the cross-sections. Therefore, Dumitrescu and Hurlin (2012) methodological technique appears to be more reliable than that of the conventional Granger causality tests. This causality test is a basic version of the Granger causality test for heterogeneous panel data models. The heterogeneous panel data models work under fixed coefficients. The linear equation is modeled as follows:

$$y_{i,t} = \alpha_i + \sum_{k=1}^{k} \gamma_i^{(k)} y_{i,t-k} + \sum_{k=1}^{k} \beta_i^{(k)} x_{i,t-k} + \varepsilon_{i,t} \tag{9}$$

[11]The Monte Carlo findings signifying that the finite-panel sample properties of the dynamics ordinary least square estimator is superior to fully-modified ordinary least square estimator therefore to identify the long-run elasticities but we applied both approaches.

where x and y are the two variables with stationary observed in time T for N individuals. For every individual, i = 1, 2,……n, t = 1,2,…….T. The individual effects, α_i and $\beta_i = (\beta_i^1, ..., \beta_i^k)'$, are assumed to be fixed in the time dimension. However, our analysis assumes that K lag orders are the same for all cross-section panel units, while also allowing the autoregressive parameters $\gamma i(k)$ and the regression coefficients $\beta i(k)$ to vary across groups and individuals. The method for assessing the presence of causality, as proposed by Granger, is to check for significant effects of past x values on the present value of y. Therefore, the null hypothesis is described as follows:

$$H_0 = \gamma_{i1} = ... = \gamma_{ik} = 0 \ \forall i = 1, ..., N.$$

It refers to the lack of causality in the panel for all individuals. The analysis suggests that some individuals may have causality, but not necessarily for everyone. Hence the alternative hypothesis:

$$H_1 = \gamma_{i1} = ... = \gamma_{ik} = 0 \ \forall i = 1, ..., N_1,$$

$$\gamma_{i1} \neq 0 or .....or \gamma_{iK} \neq 0 \ \forall i = N_1 + 1, ...N,$$

where $N_1 \in [0, N-1]$ unknown. If $N_1 = 0,$ this panel provides causality for all individuals. N_1 is shorter than N; therefore, no causality exists for all individuals and H_1 drops to H_0.

6. Empirical Findings

6.1. Cross-Sectional Dependence and Panel Unit Root Analysis

Throughout the empirical analysis, previous energy economics studies have neglected the important issue of cross-sectional dependence and heterogeneity. The data we used for the empirical analysis is expected to have a cross-sectional dependence following assumptions reported by Banerjee et al. [68] and Breitung and Pesaran [69]. The conventional panel unit root tests are inappropriate to use when datasets contain a cross-sectional dependence problem. To solve this issue, we apply a cross-sectional dependence panel unit root test developed by Pesaran [62]; that is, a cross-sectional dependence (CD) test. Table-3 displays the empirical results and we note that the null hypothesis of cross-sectional independence at a 1% significance level is strongly rejected. We also use the Pesaran [63] cross-sectional augmented (CIPS) panel root test for cross-sectional dependency data. The empirical results reported in Table-3 reveal that the null hypothesis of the panel unit root is not rejected for all the sample variables at that level. After the first differencing, all variables are found to be stationary. This observation supports the integration of all variables in equation-1.

Table-3: Cross-Sectional Dependence and Panel Unit Root Analysis

Variables	$Y_{i,t}$	$K_{i,t}$	$L_{i,t}$	$RE_{i,t}$	$NRE_{i,t}$
Pesaran CD	121.995***	8.309***	78.257***	12.221***	24.014***
P-value	0.000	0.000	0.000	0.000	0.000
The unit root test with cross-sectional dependence					
CIPS test (level)	1.353	-1.1708	2.423	4.327	-0.045
CIPS test (1st difference)	-12.042***	-11.381***	-14.605***	-20.470***	-23.514***

Notes: '***' indicates the rejection of the null hypothesis of cross-sectional independence (CD test) and the null hypothesis of unit root at 1% significance levels, respectively.

Table-4: Pedroni Panel Cointegration Analysis

Test	Statistic	Prob.	Weighted Statistic	Prob.
Alternative hypothesis: common AR coefficients (within-dimension)				
Panel v-Statistic	13.772***	0.000	9.694***	0.000
Panel rho-Statistic	1.749	0.959	3.072	0.998
Panel PP-Statistic	-6.933***	0.000	-2.887***	0.000
Panel ADF-Statistic	-8.338***	0.000	-3.841***	0.000
Alternative hypothesis: individual AR coefficients (between-dimension)				
Group rho-Statistic	4.464	1.000		
Group PP-Statistic	-4.049***	0.000		
Group ADF-Statistic	-5.568***	0.000		

Notes: ***, Denote rejection of the null hypothesis of no cointegration at 1% significance level.

After the integration of variables, we should investigate whether there is a long-run relationship between economic growth and its determinants. Therefore, our study applies the Pedroni panel long-run cointegration test developed by Pedroni [64] [65]. This proposed cointegration test contains seven test statistics: "Panel v-Statistic, Panel rho-Statistic, Panel PP-Statistic, Panel ADF-Statistic, Group rho-Statistic, Group PP-Statistic, and Group ADF-Statistic work under parametric and nonparametric frameworks". The empirical results are reported in Table-4. Out of seven test statistics, five test statistics, namely, Panel v-Statistic, Panel PP-Statistic, Panel ADF-Statistic, Group PP-Statistic, and Group ADF-Statistic, confirmed the presence of a long-run cointegration between the variables. Therefore, we may conclude that renewable energy (non-renewable) energy consumption, capital, and labor have a long-run equilibrium relationship. Moreover, we also applied two other panel cointegration approaches: Kao panel cointegration and Johansen Fisher-Type panel cointegration test developed by Kao [70] and Johansen [71]. The empirical results reported by Kao [70] and Johansen [71] cointegration tests also confirmed the presence of a long-run equilibrium relationship between economic growth and its determinants.

Table-5: Long-Run GDP Elasticities

Variable	FMOLS		DOLS	
	Coefficient	t-statistics	Coefficient	t-statistics
Dependent variable: $Y_{i,t}$				
$RE_{i,t}$	0.290***	16.389	0.252***	12.900
$NRE_{i,t}$	1.174***	20.116	0.975***	10.662
$K_{i,t}$	0.332***	7.497	0.288***	4.937
$L_{i,t}$	0.976***	14.894	1.063***	13.129
R-squared	0.992		0.998	

Note: *** indicates the significance level at 1%, respectively.

We applied FMOLS and DOLS to estimate the long-run elasticities of output. These techniques accounted for endogeneity, as well as serial correlation. The empirical findings are reported in Table-6. Our study confirms the presence of positive impact of capital on economic growth. It is noted that a 1% increase in capital increases output by 0.288-0.332%. This result is similar with Bhattacharya et al. [5] for 38 countries, Kutan et al. [13] for emerging market economies, Apergis and Payne [20] for 20 OECD countries, David [19] for OECD nations and Apergis and Payne [22] for Central American countries who also reported that capital adds to economic growth. The impact of labor on economic growth is positive and significant at 1% level of significance. We find that a 1% increase in labor increases output by 0.976-1.063%. This evidence is in line with Bhattacharya et al. [5] for 38 countries, Kutan et al. [13] for emerging market economies, Apergis and Payne [20] for 20 OECD countries, Apergis and Payne [22] for Central American countries and David [19] for OECD nations who mentioned the important role of labor force in domestic production. Renewable energy consumption has positive and significant effect on economic growth. Keeping all else is same, a 1% increase in renewable energy increases output by 0.252-0.290%. This empirical result is consistent with Kutan et al. [13] for emerging market economies, Apergis and Payne [20] for 20 OECD countries, Apergis and Payne [22] for Central American countries and David [19] for OECD nations who noted that renewable energy consumption leads economic growth. The positive and significant relationship exists between non-renewable energy consumption and economic growth. By keeping other things constant, a 1% increase in non-renewable energy increases output by 0.975-1.174%[12]. This empirical finding is similar to Bhattacharya et al. [5] for 38 countries, Kutan et al. [13] for emerging market economies who also found that non-renewable energy consumption affects economic growth positively and significantly.

[12]The empirical results of long-run elasticities of the output indicate that renewable (non-renewable) energy consumption, along with traditional inputs such as labor and capital, and economic development process in 38 countries plays a significant role. Thus, the study claims that consumption of renewable energy plays a larger role in economic output; consequently, promoting the consumption of renewable energy to ensure sustainable economic growth in the future is important.

Table-6: Heterogeneous Panel Causality Analysis

Null Hypothesis:	Zbar-Stat.	Prob.
$K_{i,t}$ does not homogeneously cause $Y_{i,t}$	5.917	3.E-09
$Y_{i,t}$ does not homogeneously cause $K_{i,t}$	15.547***	0.000
$RE_{i,t}$ does not homogeneously cause $Y_{i,t}$	2.739***	0.000
$Y_{i,t}$ does not homogeneously cause $RE_{i,t}$	14.052***	0.000
$NRE_{i,t}$ does not homogeneously cause $Y_{i,t}$	1.722*	0.084
$Y_{i,t}$ does not homogeneously cause $NRE_{i,t}$	7.731	1.E-14
$L_{i,t}$ does not homogeneously cause $Y_{i,t}$	4.647	3.E-06
$Y_{i,t}$ does not homogeneously cause $L_{i,t}$	16.641***	0.000

Note: *** and * denotes rejection of null hypothesis at 1% and 10% level

Once we confirmed the long-run relationship among the sample variables, the next step is to find the short-run causality relationship between the variables by conducting a heterogeneous panel causality test. The test needs the data series to be stationary, and our study converted the data series into the first difference. The empirical findings are reported in Table-6. The empirical analysis shows the presence of a bidirectional causality relationship between the consumption of renewable energy and economic growth. This empirical evidence is consistent with current studies such as Kahia et al. [72] for Middle East and North African (MENA) countries; Rafindadi and Ozturk [11] for Germany; Koçak and Şarkgüneşi [26] for Albania, Georgia, and Romania; Apergis and Payne [22] for Central American countries; Apergis and Payne [20] for 20 OECD countries; Lin and Moubarak [27] for China; Shahbaz et al. [28] for Pakistan; Pao and Fu [53] for Brazil; Marinaş et al. [48] for European economies; and Can and Korkmaz [44] for Bulgaria. Economic growth causes capital. This empirical result is comparable with Koçak and Şarkgüneşi [26] for Albania; Lee and Jung [45] for South Korea; Kahia et al. [72] for MENA countries; Rafindadi and Ozturk [11] for Germany; Apergis and Payne [22] for America; Apergis and Payne [23] for Eurasia; Apergis and Payne [20] for 80 economies; and Bhattacharya et al. [5] for the case of top 38 countries. The one-way causal association is noted for connecting the consumption of non-renewable energy to economic growth. This empirical outcome is contrary with studies such as

Paramati, Apergis, and Ummalla [14] on G20 economies; Kahia et al. [72] for MENA countries; Apergis and Payne [24] for 80 countries; Tugcu et al. [29] for G7 countries; Ohlan [37] for India; Dogan [39] for Turkey; and Shahbaz et al. [28] for Pakistan. Labor is caused by economic growth. This empirical result is consistent with existing studies, such as Apergis and Payne [20] for OECD economies; Apergis and Payne [22] for Central America; Apergis and Payne [23] for Eurasia; Kahia et al. [72] for MENA countries; and Koçak and Şarkgüneşi [26] for four countries namely, Albania, Bulgaria, Macedonia, and Ukraine; and Apergis and Payne [24] for 80 countries. The empirical findings suggest that non-renewables in the short-run influences economic growth; it can be interpreted that more output can be produced by promoting the use of renewable energy consumption to support sustainable economic growth.

Table-7: Long-Run Elasticities using DOLS Model (Dependent Variable: $Y_{i,t}$)

Variable	$K_{i,t}$	$L_{i,t}$	$RE_{i,t}$	$NRE_{i,t}$	R^2	Adjusted R^2
Australia	1.313***	1.396***	0.299***	0.008	0.998	0.996
Austria	0.982*	0.332	0.555**	2.012***	0.996	0.989
Belgium	-0.140	1.403***	0.052	0.661	0.984	0.956
Brazil	0.565***	1.274***	0.324**	0.284**	0.998	0.995
Bulgaria	0.022	0.461	0.403***	2.122***	0.983	0.951
Canada	0.461**	1.676***	-2.408***	0.674**	0.998	0.995
Chile	-0.124	1.127***	0.470***	0.926***	0.999	0.998
China	3.512***	0.481*	1.193**	0.482	0.999	0.997
Czech Rep.	0.145	0.404***	0.598***	2.156***	0.995	0.987
Denmark	0.439**	1.497***	0.187***	0.279	0.984	0.954
Finland	0.261	0.833***	0.709***	1.205***	0.994	0.982
France	0.054	2.281***	-0.356*	-1.204**	0.993	0.981
Germany	0.531*	1.481***	0.155*	0.107	0.990	0.971
Greece	0.169	0.711***	0.440***	1.776***	0.996	0.989
India	0.055	1.851***	-1.927***	-0.293	0.999	0.998
Ireland	0.554***	1.222***	0.311***	0.765***	0.999	0.998
Israel	0.133	1.537***	-0.033	0.333	0.997	0.993
Italy	-0.082	1.434***	-0.021	0.534**	0.990	0.971
Japan	-0.593***	1.506***	0.299**	0.447	0.986	0.962
Kenya	0.251**	1.209***	0.387**	0.290	0.998	0.996
Korea, Rep.	0.235	1.131***	0.103***	0.902***	0.998	0.996
Mexico	-0.124	1.274***	0.362***	0.639**	0.996	0.988
Morocco	-0.087	1.511***	-0.102	0.211	0.993	0.981
Netherlands	0.263**	1.608***	0.082***	0.094	0.998	0.995
Norway	-0.658**	2.252***	-0.753**	-0.161	0.990	0.973

Peru	0.088	1.072***	0.430***	0.968***	0.998	0.995
Poland	0.521**	2.573***	1.058***	-2.566***	0.990	0.971
Portugal	-0.098	1.505***	0.161	0.337*	0.993	0.980
Romania	-0.057	0.310	0.925	2.450	0.762	0.316
Slovenia	-0.115	0.801***	0.281***	1.600***	0.999	0.997
South Africa	0.441*	1.435***	-0.592	0.367	0.995	0.987
Spain	-0.234	1.623***	-0.365***	0.272	0.992	0.979
Sweden	0.731**	0.392	1.014***	1.710***	0.993	0.980
Thailand	0.202***	1.167***	-0.066	0.766***	0.998	0.996
Turkey	0.289***	1.815***	-0.775***	-0.327	0.998	0.996
Ukraine	-0.875**	0.400	0.465***	2.660***	0.967	0.905
United Kingdom	-0.434**	2.036***	-0.158***	-0.662**	0.996	0.989
United States	0.810***	1.622***	0.202	-0.348	0.997	0.992

Note: ***, ** and * donates 1%, 5% and 10% levels respectively.

Table-5 presented the panel data analysis of long-run economic growth elasticities. Further, the study aimed at analyzing the time series of long-term economic growth elasticities for each country. The time-series analysis for individual nations is critical to knowing the dynamic effect of renewable energy use on economic growth. The elasticity of the long-run output is estimated by applying the DOLS model. Moreover, The Dynamic Ordinary Least Square (DOLS) model is an alternative long-run technique and moreover, it has advantage over Fully Modified Ordinary Least Square (FOLS). The unique feature of Dynamic Ordinary Least Square provides efficient and effective estimator asymptotically. Stock and Watson (1993) and Saikkonen (1991) highlight that Dynamic Ordinary Least Square can be alternative for Fully Modified Ordinary Least Square as advanced". Last but not least, it is indicated by Mansson et al. (2017) that the DOLS approach "*includes some extra control variables in order to correct for the small sample bias caused by an endogeneity problem*". This shows that the DOLS approach seems to solve the issue of potential endogeneity. The findings are shown in Table-7. The long-run elasticities of economic output with respect to consumption of renewable energy and are positive for Australia (0.299), Austria (0.555), Brazil (0.324), Bulgaria (0.403), Chile (0.470), China (1.193), the Czech Republic (0.598), Denmark (0.187), Finland (0.709), Germany (0.155), Greece (0.440), Ireland (0.311), Japan (0.299), Kenya (0.387), Korea Republic (0.103), Mexico (0.362), the Netherlands (0.082), Peru (0.430), Poland (1.058), Slovenia (0.281), Sweden (1.014), and Ukraine (0.465). For these 22 nations, the consumption of renewable energy has a considerable and positive impact on economic output. This analysis suggests that the use of renewable energy will generate more economic output. This finding is consistent with previous studies such as Fotourehchi [46] for 42 developing countries; Anwar et al. [47] for 29 nations; Ntanos et al. [49] in the case of 25 European economies; Bhattacharya et al. [5] in 23 nations; Koçak and Şarkgüneşi [26] for nine countries; Kahia et al. [72] for MENA countries; Bhattacharya et al. [12] for 85 developed and developing countries; and Haseeb et al. [58] for Malaysia.

However, long-run output elasticities reveal the negative and substantial effect of the consumption of renewable energy on economic growth, which is confirmed for Canada (-2.408), France (-0.356), India (-1.927), Norway (-0.753), Spain (-0.365), Turkey (-0.775) and the United Kingdom (-0.158). This result indicates that countries started consuming non-renewable energy in place of the consumption of renewable energy hinders economic growth. This empirical result is similar to that of Maji and Sulaiman [42] for 15 West African countries, Lee and Jung [45] for South Korea, Neitzel [73] for 22 OECD countries, Sebri and Ben-Salha [33] for BRICS countries, and Bhattacharya et al. [5] for the case of India, Ukraine, the US and Israel. For Belgium (0.052), Italy (-0.021), Israel (-0.033), Morocco (-0.102), Portugal (0.161), Romania (0.925), South Africa (-0.592), Thailand (-0.066), and the United States (0.202), the consumption of renewable energy has a negative and positive but insignificant effect on economic growth. Theoretically, the effect of consumption of renewable energy on economic growth can be negative or positive but statistically, it can be insignificant. Therefore, we write the consumption of renewable energy has a negative and positive but insignificant effect on economic growth. For example, Belgium (0.052), Portugal

(0.161), Romania (0.925) and the United States (0.202), the coefficients values are positive but their probability values are insignificant and Italy (-0.021), Israel (-0.033), Morocco (-0.102), South Africa (-0.592), and Thailand (-0.066), the coefficients values are negative and also their probability values are insignificant. We infer that the consumption of renewable energy is at the initial stage for such nine nations. This result is similar to existing studies such as Bhattacharya et al. [5] for 11 countries.

Capital elasticities are very low as compared to employment in the following nations: Australia (1.396), Belgium (1.403), Brazil (1.274), Canada (1.676), Chile (1.127), China (0.481), Czech Republic (0.404), Denmark (1.497), Finland (0.833), France (2.281), Germany (1.481), Greece (0.711), India (1.851), Ireland (1.222), Israel (1.537), Italy (1.434), Japan (1.506), Kenya (1.209), Korea Republic (1.131), Mexico (1.274), Morocco (1.511), the Netherlands (1.608), Norway (2.252), Peru (1.072), Poland (2.573), Portugal (1.505), Slovenia (0.801), South Africa (1.435), Spain (1.623), Thailand (1.167), Turkey (1.815), the United Kingdom (2.036) and the United States (1.622). These nations reflect a study deployment; the adoption of renewables is connected with long-run employment creation. This empirical evidence is consistent with current studies such as Koçak and Şarkgüneşi [26] for 9 countries; Rafindadi and Ozturk [11] for Germany; Maji and Sulaiman [42] for West Africa; Kahia et al. [72] for MENA nations, Bhattacharya et al. [12] for 85 countries; and Apergis and Payne [20] for 20 OECD countries. Regarding Austria (0.332), Bulgaria (0.461), Romania (0.310), Sweden (0.392), and Ukraine (0.400), these countries exhibit a positive but statistically insignificant effect on economic growth. Similar findings are documented by Bilgili and Ozturk [15) in the case of G7 countries and Salim and Rafiq [25] for six countries.

The long-run elasticities of economic output with respect to capital are significant and positive for Australia (1.313), Austria (0.982), Brazil (0.565), Canada (0.461), China (3.512), Denmark (0.439), Germany (0.531), Ireland (0.554), Kenya (0.251), Netherlands (0.263), Poland (0.521), South Africa (0.441), Sweden (0.731), Thailand (0.202), Turkey (0.289), and the United States (0.810). This result shows that capital promotes economic growth. Similar results are also established by Maji and Sulaiman [42] for West Africa; Anwar et al. [47] for 29 countries; Kahia et al. [72] for MENA countries; Rafindadi and Ozturk [11] for Germany; Koçak and Şarkgüneşi [26] for nine countries; Bhattacharya et al. [5] for top 38 countries; and Bhattacharya et al. [12] for 85 developed and developing countries. For Japan (-0.593), Norway (-0.658), Ukraine (-0.875), and the United Kingdom (-0.434), capital has a negative but statistically significant effect on economic growth. For Belgium (-0.140), Bulgaria (0.022), Chile (-0.124), Czech Rep. (0.145), Finland (0.261), France (0.054), Greece (0.169), India (0.055), Israel (0.133), Italy (-0.082), Korea, Rep. (0.235), Mexico (-0.124), Morocco (-0.087), Peru (0.088), Portugal (-0.098), Romania (-0.057), Slovenia (-0.115) and Spain (-0.234), capital has a positive and negative but insignificant effect on economic growth. This analysis is consistent with existing studies such as Bilgili and Ozturk [15] for G7 countries.

The long-run elasticities of economic output with respect to the consumption of non-renewable energy are positive for Austria (2.012), Brazil (0.284), Bulgaria (2.122), Canada (0.674), Chile (0.926), Czech Rep. (2.156), Finland (1.205), Greece (1.776), Ireland (0.765), Italy (0.534), Korea, Rep. (0.902), Mexico (0.639), Peru (0.968), Portugal (0.337), Slovenia (1.600), Sweden (1.710), Thailand (0.766), and Ukraine (2.660). For the eighteen countries, the consumption of non-renewable energy has a positive and substantial effect on economic output. This analysis suggests that the use of non-renewable energy will generate more economic output. Similar results are reported by Maji and Sulaiman [42] for West Africa; Kahia et al. [72] for MENA countries; Rafindadi and Ozturk [11] for Germany; Bhattacharya et al. [5] for top 38 countries; and Bhattacharya et al. [12] for 85 developed and developing countries. France (-1.204), Poland (-2.566), the United Kingdom (-0.662) exhibit a negative but statistically significant effect, which confirms that the consumption of non-renewable energy hinders economic growth. For Australia (0.008), Belgium (0.661), China (0.482), Denmark (0.279), Germany (0.107), India (-0.293), Israel (0.333), Japan (0.447), Kenya (0.290), Morocco (0.211), Netherlands (0.094), Norway (-0.161), Romania (2.450), South Africa (0.367), Spain (0.272), Turkey (-0.327), and the United States (-0.348), the effect of the use of non-renewable energy on economic growth is mixed. This finding clearly shows that the majority of countries have shifted from the consumption of non-renewable energy to renewable energy consumption, which will ensure environmental quality and pave the path toward sustainable development.

7. Conclusions and Policy Implications

Nations worldwide have recently been considering sustainable development and increasing the consumption of renewable energy sources, such as hydropower, solar PV, wind power, and geothermal power. High and unpredictable vitality costs and geopolitical discussion encompassing the consumption of non-renewable energy sources will boost the growth and market openness of sustainable power sources by different governments. This study evaluates the potential impact of sustainable and non-sustainable energy sources on economic growth across the nations.

This study applied heterogeneous panel approaches and established the elasticities of long-run output with the consumption of renewable (non-renewable) energy, labor, and capital for major renewable energy-consuming countries, following RECAI. This empirical analysis shows that the use of renewable energy has a positive and considerable effect on economic growth for Ukraine, Sweden, Slovenia, Poland, Peru, the Netherlands, Mexico, Korea Republic, Kenya, Japan, Ireland, Greece, Germany, Finland, Denmark, the Czech Republic, China, Chile, Bulgaria, Brazil, Austria, and Australia. The majority of which have already moved toward renewable energy sources. For instance, the Renewable Energy Act encourages the implementation of renewable energy use in China[13] regarding its 2005 and 2009 amendments. The National Energy Agency[14] and National Development and Regulation Commission' [1] is responsible at the national, regional, and local levels for setting goals. The Australian government also supported renewable energy projects schemes such as large-scale (Hydro energy and Wind energy) and small-scale renewable energy (Solar) projects following amendments on June 23, 2015. They expected that renewable energy elasticity production would be 23.5% by 2020. The Japanese government has an encouraging variety of renewable sources, such as nuclear, hydropower, geothermal, and other (PV, Wind, and MSW) from 366.4, 95.4, 3.2, and 10.2 in 2010, respectively, and they are projected to increase to 437.4, 85.6, 3.3, and 31.2 by 2030, respectively. Japan is expected to have 22% to 24% renewable electricity by 2020. Ireland's economic goal is to produce 20% renewable electricity by 2020, while Sweden aims to have at least 50% renewable power by 2020. Brazil's government signed an agreement with the US government in June 2015 to expand renewable energy use to 20% by 2030 [74]. These 22 countries have started to shift from non-renewable energy use to renewable energy in long-run. For many of these nations, the deployment of renewable sources is creating employments in the economy. For example, Japan will be creating a trillion JPY market and 110 thousand employment opportunities in the solar industry by 2020 [74].

Secondly, renewable energy use has a significant and negative effect on economic growth in Canada (-2.408), France (-0.356), India (-1.927), Norway (-0.753), Spain (-0.365), Turkey (-0.775) and the United Kingdom (-0.158). It highlights the characteristics of a few nations in the energy mix, which can lead to a slow development with an adverse impact on economic growth. For instance, Canada is rich in natural gas and crude oil, and 91% of

[13] www.npc.gov.cn
[14] www.en.ndrc.gov.cn

energy products have been exported to the US.[15] The fastest-growing sources of renewable energy, such as wind and solar are producing only 3% of renewable energy. The Indian energy sector is mainly based on coal (69%), with 12% hydropower and 5% non-hydro renewables. Based on the allocation of funding, renewable energy sources are in the prosperous states of India; that is, Rajasthan, Gujarat, and Tamil Nadu. The Turkish Government is implementing the National Renewable Energy Action Plan (NREAP) to achieve 30% of its total renewable energy installed capacity by 2023. We examined seven nations' energy-mix and observed their present scenario of renewable energy sources; therefore, we advise that non-renewable energy sources should be substituted with renewable energy sources for better economic development. Such seven countries must pursue a steady and incremental deployment process.

Thirdly, for nine economies such as Belgium, Italy, Israel, Morocco, Portugal, Romania, South Africa, Thailand, and the United States, we find that the consumption of renewable energy has an insignificant impact on economic growth. One conceivable clarification regarding these nine nations is that they have not had the option of realizing the production of renewable electricity sources for achieving economic output. Hence, the policy advisors of the respective countries will focus on funding renewable energy sources; consequently, renewable energy sources can be used to raise demand for energy from various economic activities. For example, in Belgium, renewable energy production is 2% in 2005 and is expected to have 13% of electricity from renewable sources by 2020. To reach the target, the country has to allocate more capital for development of renewable energy efficiency and encourage the use of renewable energy consumption by providing different incentives and public private partnership investment, subsidies. Israel has largely relied on

[15]Percentage of Canadian production

the hydrocarbon-led energy sector [75][16] and reports 33% of diesel and natural gas electricity production and 6% of coal. The Israel nation needs to adopt the use energy renewable energy consumption by reducing the use of non-renewable energy resources and ensure sustainable development by lowering the carbon emissions. Recently, these nine nations relied heavily on foreign trade. Thus, low-carbon emissions energy-mix will not have a considerable and unfavorable impact on economic growth. To maintain the stability of economic growth and sustainability development, the countries has to encourage the use of renewable energy resource by increasing energy efficiency, furthermore, which will ensure stable economic growth and sustainability growth. The consumption of renewable energy sources has grown for the vast majority of nations in the last two decades. The results of the implementation of renewable energy are unique across nations due to many factors, as addressed in various reports by international bodies. All the nations have to encourage the use of renewable energy consumption as well as allocate more funding to renewable energy projects, it's not only reduced carbon emissions but also ensure sustainable growth. Therefore, the policy makers and governments need to reframe the new policies, which will help to ensure future aspects.

Lastly, previous studies have shown positive relationship between renewable energy consumption and economic growth. Therefore, our study also looked into whether those countries are constantly encouraging renewable energy consumption by increasing capital. Interestingly, our study found that only 22 countries have shown positive relationship between renewable energy consumption and economic growth. A study by Bhattacharya et al. (2016) also examined same group of countries and variables but found that renewable energy consumption has a positive impact on economic growth for 23 countries. Our study confirmed that renewable energy consumption has a negative impact on economic growth in 9 countries while Bhattacharya et al. (2016) established negative impact only for 4 countries.

[16](IEC) Israel Electric Corporation

This study finds that the relationship between renewable energy and economic growth is dynamic. Further, it shows that additional investments will improve renewable energy production (consumption) and will have impact on economic growth.

All countries are moved towards a low carbon emission and planning to develop sustainable economy. Therefore, we need an essential transformation of economic structure and energy transformation. The developed economic, environmental policies and other policies may play a significant role in fostering and steering the transformation but governments will need to ensure that policies are implemented as well as monitored effectively. Environmental policies are essential for economic development and sustainable economy. Therefore, the strength of environmental and energy policies to achieve their objective based on the country process leading to policy adoption. Here, every country has a separate policy which may be encourage their energy sector and may not. To develop renewable energy sector, we need financial support for development of green technologies, after that we need to start applying those technologies into industries and households. To use renewable energy technology not only reduces carbon emissions and also strengthens energy efficiency. Last but not least, energy policies may have different effects due to different energy policy stringency, development stage, governmental institutions, market freedom etc. in different countries.

This work highlights a few shortcomings in describing the process of growth, which considers renewables as a source of energy. Whereas the implementation of renewables policies is based on several factors within and across nations, it is important to develop a long-term plan to address the capacity, costs, regulatory barriers, infrastructure, and institutional structure of any nation. For instance, the combination of renewables and grids presents a significant challenge as grids are typically used to supply electricity generated by fossil fuel. This situation was highlighted by Desideri et al. [76]. There are considerable insights like the problem of and the best way to increase renewable investment [77]. This study does not consider these issues, which may have direct as well as indirect effects on economic growth in the process of renewable deployment. Developing an investment climate, improving human resources, and removing all financial and political obstacles are significant steps toward the deployment of renewable sources. For example, this process has also included in the majority of OECD nations, as well as other nations. Financial considerations, investment subsidies, solar cells sales tax exemptions, feed-in tariffs, tax or credit incentives, green certificate trading, and establishing quota are significant tools for continuous deployment. Power planners, international cooperation organizations, government utilities on energy policy, and related organizations need to work together to enforce renewable energy deployment policies.

Funding

Fundamental Research Funds for the Central Universities [grant number 63192807]
Tianjin Philosophy and Social Sciences Planning Project [grant number TJGL18-003]

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Appendix-A

Table-A: Definition of Acronyms

RECAI	Renewable Energy Attractiveness Country Index
REN21	Renewable Energy Policy Network for the 21st Century

FMOLS	Fully Modified Ordinary Least Squares
DOLS	Dynamic Ordinary Least Squares
NREAP	National Renewable Energy Action Plan
NEA	The National Energy Agency
NDRC	National Development and Regulation Commission