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The Determinants of Renewable Energy Production– A Global Study on Panel Data

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ABSTRACT
Objective: Due to the environmental concerns and excessive utilization of fossil fuels, globally the nations are actively pursuing the transition toward Renewable Energy (RE). Therefore, to mitigate the CO_2 emissions and address the energy security, the production of energy from renewable sources is the ultimate solution, hence identifying the drivers of renewable energy production (REP) is imperative.
Research Gap: However, the focus of the earlier studies was on the determinants of RE consumption (REC) whereas the focus of this study is on the determinants of REP. The REP represents the supply side of economics and excludes the energy import, transmission and distribution losses.
Design/Methodology/Approach: The study is based on global panel data of 133 countries from 1990 to 2020 and applies panel data estimation techniques.
The Main Findings: The study revealed that economic variables such as GDP per capita and trade openness, as well as demographic variables (urban population), drive the REP. Conversely, energy-related variables, i.e., electricity generation from coal, oil, natural gas and nuclear sources slow down the adoption of REP. Similarly, the negative association between CO_2 emissions per capita and REP is interesting. This suggests that the lobby elements for favoring the utilization of fossil fuel bar the REP.
Theoretical/Practical Implications of the Findings: This study is helpful for policymakers and researchers in understanding the dynamics of the determinants of the REP while devising energy policies.

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1. Introduction

Energy is considered the engine of economic growth. The higher economic growth associated with rapid industrialization and increased economic activities demands excessive utilization of electricity. Although high economic growth is desirable for every country, however, the issue of environmental degradation arising due to the excessive utilization of fossil fuel required for energy generation is undesirable. According to (Hao & Shao, 2021), human society is facing the risk of climate change. The main contributors to climate change are greenhouse gases, which are the resultants of the burning of fossil fuels. The (Global Energy Review 2021, 2021), states that the contribution of the emissions from the energy sector after the pre-industrial stage is nearly three-quarters causing a higher global average temperature of 1.1°C as evident from the ostensible harsh weather and climate conditions, therefore, the energy sector should be the center of the solution.

In the wake of the numerous environmental threats arising from the burning of fossil fuel in the process of energy generation, tackling these environmental threats and degradations on a war footing basis multiple solutions have been proposed by experts. For instance, (Kinab & Elkhoury, 2012) argued that REP and REC are the most prominent and vibrant solutions. (Timmons et al., 2014) are of the view that the 21st century is witnessing the transition toward the adoption of RE as a solution instead of fossil fuels due to various concerns including climate change, energy security, and the cost of fossil fuels and technological change. (Aguirre & Ibikunle, 2014) highlighted that production and consumption from RE sources have vital socio-economic, political, and environmental impacts, therefore the transition toward RE is a vibrant action in the list of socio-politico activities. (Inglesi-Lotz, 2016) argued that globally the increased proportion of green energy in the energy mix is encouraged due to its energy security and environmental aspect, therefore, promoting RE is not only important from an environmental aspect but also from the perspective of economic conditions of the nations.(Luni & Majeed, 2020) also argued that enhancing the share of RE by 4.5154% in the total share of energy will reduce carbon emissions, thus RE due to its environmentally friendly nature is an attractive alternative to carbon-emitting sources of energy in South Asian countries.

Similarly, (Ouikhalfan et al., 2022) suggested that better efficiency; replacement of fossil fuel with green hydrogen, renewable energy sources, carbon capture technology, biomass and the adoption of a circular economy with innovative technologies are the list of options. Likewise, (Hu et al., 2022) express that fossil fuel-based energy is the main detrimental factor behind environmental degradation, thus adopting the RE is the requirement of the present time and the implementation of the COP21 of the Paris Agreement's mission. (World Energy Transitions Outlook 2022: 1.5°C Pathway, 2022), reports that energy transition based on the RE is the most authentic opportunity to mitigate environmental degradation and this opportunity entails multiple benefits like energy security, national resilience and the building of a sustainable climate-proof global economy. It is evident from the literature, that various solutions are proposed, however, the adoption of RE to cater for the climate crises is widely acknowledged, therefore, to mitigate climate change-related problems, promoting RE is urgent. Thus promoting power production from from RE sources is not only important for tackling the environmental degradation issue but will also be critical for the socio-economic prosperity of the nations.

Due to the multifaceted benefits of the RE and its importance as endorsed by the experts, knowing about the progress of the RE becomes inquisitive. The (Renewable Energy Statistics 2019, n.d.) reports that by 2050 the share of RE in the total global energy mix will be two-thirds. Similarly, (Global Energy Review 2021, 2021) reported a 30% increase in the generation from RE sources during the year 2021, indicating the highest yearly surge since the Industrial Revolution period and with a dominancy of generation from wind and solar (Renewable Energy Statistics, 2022) reports that a 6% addition to the RE capacity reaching 295 GW during the year 2021 is recorded and an addition of 8% is expected in the year 2022. Likewise, (Global Energy Perspective,2022) reports that globally the cost of wind and solar has become competitive and the RE will serve the purpose of baseload power plants by 20230, the share of generation of electricity from renewable sources will surge to 50% in the energy mix and 85% by 2050 by replacing the thermal generation.

The future projections and pledges as expressed by the experts in the literature indicate that the transition process of replacing the utilization of dirty fuel with increasing the proportion of RE in the energy mix is quite active. Thus the positive impact of enhanced production from the RE will ameliorate the environment. Therefore, to replace energy production through the utilization of fossil fuels, embracing energy production from RE is pivotal. However, without comprehending the dynamics of RE, the active transition toward green energy may not be achieved in the desired time, therefore, investigating the RE transition from the perspective of its production and consumption side is vital. According to the study conducted by (Wu et al., 2006), the demand side of energy targets the total final energy consumption, whereas the supply side highlights the total primary energy production and normally the total energy supply is not equal to the total final energy consumed due to various factors. (Bayale et al., 2021) argued that the focus of the earlier studies was mainly on the REC, however, to enhance the share of RE in the total energy mix, the production of electricity from renewable is the centre of attention in African countries, therefore, understanding the factors of REP is imperative.

Thus extending this perspective, the REP represent the generation from renewable energy falls under the purview of the supply side, whereas the REC demonstrating the utilization of the energy by the end users falls under the domain of the demand side. Moreover, the difference in energy produced and consumed may occur due to many factors, like the units of electricity losses during the transmission, and distribution processes, and the utilization of imported energy for consumption, thus REP and REC have different aspects. (Carley et al., 2017) believe that energy consumption is positively associated with energy production due to the reason that industrial growth as a result of economic expansion will drive the demand and subsequently the nations will focus on developing RE generation. (Wu et al., 2006) also argue that demand-side and supply-side policies are the classifications of national energy or climate policies where the former focuses on promoting energy conservation among the end consumers and the latter considers various other options like stimulating the exploration of other energy sources or allowing the import of energy for meeting the demand.

The available literature indicates that the policy direction of the demand and supply sides have different patterns. (Wu et al., 2006) in their study argued that international donors, investors and policymakers give due importance to quality information regarding enhancing the share of RE. They further argued that the existence of effective policies gives the investors, Clean Development Mechanism funders and other stakeholders' confidence in enhancing the share of REP by working with governments to implement policies. Based on the arguments of the scholars exploring the nexus of REP and its factors will provide a specific avenue to the policy makers for inclusion in the policy-making which will augment the supply of RE in the energy mix.In one study (Matsumoto & Matsumura, 2022) argued that for promoting the deployment of RE as a solution to curb CO2 emissions, understanding the factors responsible for replacing dirty fuel with clean and green resources is imperative. According to (Przychodzen & Przychodzen, 2020) various factors including economic and technical determine the production of energy from renewable sources. The economic growth measured by GDP positively affects the REP. Similarly (Bayale et al., 2021) state that the determinants of REP are classified as socio-economic, environmental, technical, political and country-specific classifications in various research studies, however, GDP per capita, energy investment, carbon emissions and urbanization are the driving factors of the REP in west African countries.

Therefore, it is crucial to study the determinants of the REP from the perspective of its specific implication, which the earlier studies have not explored. Moreover, the existing studies have not empirically explored the impact of power generation from fossil fuel-based power plants on the generation of energy from RE sources on a global level. The impact of analyzing the relationship of generation from the fossil fuel-based power plant with REP is to identify the impact of the factors limiting the production of energy from renewables. Due to the growing electricity demand, the supply of clean and green energy is only possible if the key factors responsible for enhancing its share are highlighted for inclusion in the policy-level decision. Further, the earlier studies have not considered identifying the determinants of REP for a large sample of global panel data.

This research study aims to bridge this gap and contribute to the existing knowledge by investigating the key determinants of REP. Based on the classification considered by the studies conducted by (Aguirre & Ibikunle, 2014a; Marques & Fuinhas, 2011; Przychodzen & Przychodzen, 2020) the determinants are thematically classified into economics, demographic and environmental categories. The economic determinants including the GDP and trade openness are important elements in contributing to the development of RE developments. Regarding the economic implication of energy generation from renewable sources, (Jeon, 2022b) found that in the long run economic growth is associated with the deployment of RE and will have spillover effects on the other sectors. Thus economic growth is positively associated with RE development. The CO2 emission used as a proxy for the environment is the main determinant factor having an important role in the development of clean energy and may drive the production from the RE.

According to (Jeon, 2022a), the development of the RE is not only important from the economic perspective but has also an environmental impact by mitigating the social cost of CO2 emissions, thus the development of cleaner technology is supported. Similarly, the urban population is representative of the demographic and is also the driving factor affecting the generation of electric power. Due to population growth, the energy demand grows and consequently, the production of electricity will meet the required demand.

The energy-related variables assumed in this research study are novel in the sense that no study has been found which has specifically investigated the link of REP with energy production from non-renewable sources on a global panel, however, (Aguirre & Ibikunle, 2014) in their study while exploring the determinants of renewable energy growth for African countries have used energy production from oil, coal, natural gas and nuclear sources as independent variables. They are of the view that the results derived from the analysis of these determinants proved the theoretical perspective, which states that higher generation from coal, oil, natural gas and nuclear sources will act as a barrier to harnessing the potential of environmentally conducive renewable energy sources. Therefore, including these in this current study will serve as an additional supplement to the existing literature.

Hence, based on global panel data for 133 global countries covering the period from 1990 to 2020 this study has been carried out for exploring the thematic determinants of the REP. The thematic variables include GDP per capita, trade openness, urbanization, CO2 emissions, and energy production from nuclear, natural gas, coal and oil. The empirical results will help understand the supply side of economics and its driving factor imperative for increasing the production of electricity from the RE, thus causing a shift toward a green economy. This will further help the policymakers in making an informed decision regarding the implementation of renewable energy policies to support electricity production from renewables.

Therefore, the purpose of this research study is to explore the determinants of REP and are classified into economic, demographic, urbanization, environmental and energy-related variables. The empirical evaluation of these determinants will reveal whether these have an impact on the REP or otherwise.

The research study is structured in the following manner: Section 2 provides the literature review. Section 3 describes the theoretical background, data and methodology. Section 4 covers the data analysis providing details of statistics and selection of the econometric models. Section 5 contains the conclusion of the research study.

2. Literature Review

The environmental concern associated with the utilization of fossil fuels for power generation has shifted the focus of the nations towards the utilization of RE sources for electricity production. The environmentally conducive nature of RE has given an impetus to its development as it helps to mitigate the environmental degradation impacts, therefore, identifying the enablers and barriers in the journey of transition toward a low-carbon economy is crucial. In this regard, multiple studies have been conducted to identify the facilitating factors to support the development of RE. This study has grouped these factors into economic, demographic, environmental and energy and based on the relevant literature they are explained as follows.

2.1. Economic Determinants

Economic growth and its impact on trade openness in relation to the enhanced production from RE has been explored in many studies. (Marques et al., 2010) in their study conducted for European Union (EU) and Non-EU countries measured the GDP in absolute terms representing the economic size of the country and expected that higher utilization of RE is correlated with increased income due to the following two reasons (i) the higher income is capable of absorbing the high cost of RE (ii) availability of more resources promote the development of RE. (Omri & Nguyen, 2014) argued that economic growth-driven economic activities will increase the demand for the consumption of RE required for the production of goods and services and the window of trade openness will facilitate the transfer of RE technologies and thus the production from RE sources will increase, consequently the CO2 will decline.

(Aguirre & Ibikunle, 2014) are also of the view that economically rich nations will support deploying RE technologies by offering incentives. (Cadoret & Padovano, 2016) highlighted that the expected sign of GDP per capita and its growth can be either positive or negative following the traditional Slutsky equation. At the time of the income effect, energy production and subsequent consumption will grow and consequently, the GDP per capita will increase whereas the substitution effect in response will meet the peak demand for energy by supplying RE-based electricity generation.

Empirically multiple studies have explored the relationship between trade openness economic growth and RE consumption. For instance, (Marques et al., 2010) revealed that the relationship between the RE and income is positive and significant for EU countries and negative for non-EU nations. Another study conducted by (Omri & Nguyen, 2014) on the global panel for RE consumption while using the dynamic panel model categorized countries as high-income, middle-income and low-income, revealed that for high-income countries economic growth has a positive relationship whereas for middle and low-income panels it has a negative impact which indicates that the higher incomes countries are more concerned about the environment issues whereas the other panels may not. On the other hand, the relationship between RE consumption and trade openness for higher-income panels is negative and the opposite for other panels.

(Aguirre & Ibikunle, 2014) found that GDP per capita is negatively associated with REP with insignificant impact. They are of the view that since environmental-related variables were also considered in the econometric model income is considered the less powerful driver of RE in contrast to the environmental-related variables. (Cadoret & Padovano, 2016) found that the relationship of RE with per capita GDP and its contemporaneous growth is significant and negative, indicating the energy required for increased economic activities may not be met from the supply of RE, rather the fossil fuel-based generation will meet the demand due to its elasticity thus causing a decrease in the overall utilization of RE. On the other hand, the nexus between the GDP and RE is significant and positive indicating that the higher energy demand encourages investment in REP. However, both effects may cancel each other and result in a neutral impact. Conversely,(Bayale et al., 2021; Przychodzen & Przychodzen, 2020) explored that the GDP per capita and REP are positively associated, implying that higher income favours the generation from the RE sources.

2.2. Demographic Determinants

According to (Aguirre & Ibikunle, 2014) the energy need of the country can be represented by the inclusion of population growth, but the impact of this variable on the need for electricity may be uncertain as the higher energy demand may be fulfilled either by producing electrons from fossil fuel-based power plants or RE sources of energy. On the other hand, (Escoffier et al., 2021) think that for the deployment of solar energy, the annual sunshine is also an important factor but due to the time-invariant effect, it may be inappropriate in our specification, however, to assess the solar PV potential the urbanization factor may be an important determinant. The higher urbanization rate may indicate that the existence of a higher number of buildings and roofs facilitating the energy production from solar, conversely at a utility-scale where solar PV is installed on farm levels in non-urban areas may represent the higher deployment of solar energy. Thus the impact of this variable may not be conclusive.

Empirically the studies conducted by (Aguirre & Ibikunle, 2014; Akintande et al., 2020; Escoffier et al., 2021) also found that urbanization has a significant and positive impact on the deployment of the RE. According to (Bourcet, 2020) a consensus has been found on the overall positive impact of the population variable on the deployment of the RE and is also the main determinant of RE. Similarly, the study conducted by (Bayale et al., 2021) revealed that the urban population has a positive and significant impact on the generation from the RE intimating a supporting role in promoting the development of RE.

2.3. Environmental Determinant

Environmental degradation due to the higher concentration of CO2 emissions is the main driver pushing the development of RE to replace conventional sources of energy. According to (Marques et al., 2010) the higher uncontrollable emissions of greenhouse gases from CO2, chlorofluorocarbons, methane, nitric acid and ozone continuously raise the average global temperature causing unwanted repercussions for humans. But among these emissions sources, CO2 has been held the most responsible factor for this environmental impact. On the other hand, (Omri & Nguyen, 2014) are of the view that in the absence of policies supporting RE, high economic growth is associated with higher CO2 emissions may spur the demand for production for RE sources and consequently reduce emissions. The mitigation of CO2 may again cause a decline in the installation of new RE projects. Similarly, (Aguirre & Ibikunle, 2014) used CO2 emission as a proxy for environmental concerns and anticipated a positive impact of CO2 emissions on the deployment of RE positive relationship. Likewise, (Cadoret & Padovano, 2016) are of the view that CO2 emissions act as a stimulating factor for enhancing the utilization of RE for the EU nations. However, (Escoffier et al., 2021) term the decline in the carbon emissions causing climate change as an environmental commitment for each nation and predict that the higher growth in CO2 emission will indicate the minimum environmental commitment and lower deployment of RE.

The empirical relationship between RE deployment and CO2 has been explored by many studies For instance, (Aguirre & Ibikunle, 2014a) determined that the impact of CO2 is positive and highly significant with the supply of RE and represents the commitment of the countries toward the goal of mitigating the green greenhouse gas emission. Similarly, the studies conducted by (Omri & Nguyen, 2014); and (Cadoret & Padovano, 2016) also revealed that with RE consumption the impact of CO2 is positive and significant.

Conversely, the study conducted by (Marques & Fuinhas, 2011) revealed that the relationship between the RE supply and CO2 emission is negative which was not expected implying that the voices of the proponents of the environmental concerned groups are not effective. Even for an individual source RE deployment (Escoffier et al., 2021) found a negative relationship between solar PV deployment and carbon emission indicating that the increase in CO2 emissions decreases the deployment of RE, hence the environmental factor may not drive the deployment of environmental conducive energy, rather the higher prices of oil may shift the demand toward the installation of RE power projects. (Bayale et al., 2021) while applying the Modified Least Squares (FMOLS) and Dynamic Ordinary Least Square (DOLS) found that the relationship between the RE production and CO2 for West African Economic and Monetary Union (WAEMU) countries is negative implying that less generation from RE allows Non-RE to emit higher emissions.

2.4. Energy-related Determinants

The availability of energy for the end consumer is desirable but the dominancy of the energy mix by the conventional sources has a determinantal impact on society. Numerous studies have identified the existence of lobbies pushing the utilization of fossil fuels for power generation in the global energy mix. This fact is also acknowledged by (Marques et al., 2010) while supporting the earlier research studies, argued that the strong lobby for conventional sources of energy influences the decision makers to support polluted sources like oil and coal for electricity generation and consequently slows down the pace of development of clean energy. The authors further narrate that the higher generation of power from natural gas and nuclear may not act as a heavy polluter but discourage the generation from RE sources. (Aguirre & Ibikunle, 2014) also foresee that the energy mix of the countries largely occupied by fossil-based power generation will less likely consider the deployment of RE.

The studies conducted by (Marques & Fuinhas, 2011) for the EU countries empirically demonstrated that the association between the generation from fossil fuel and RE is negative and significant, thus showing that the industrial lobby acts as a restraint force blocking the development of RE. Another study conducted by (Aguirre & Ibikunle, 2014) on a sample of 38 counties selected from the EU, BRIC and OECD also found a negative relationship between power generation from the nuclear, natural gas, crude oil and coal sources with the energy generation from the RE sources and argued that higher reliance on these sources for energy generation acts as a barrier to deploy the of RE. The Authors also argued that the generation from nuclear can be termed as a green generation but due to the lack of consensus on the safety concerns due to various incidents like the Fukushima nuclear incident in 2011, the power generation from these sources is treated as a traditional source of generation and therefore negatively impacts the deployment of RE significantly.

The review of the literature indicated that various studies have been conducted on identifying the factors affecting the development of renewables, however, there is a dearth of studies clearly defining the flow of energy from the production and consumption side. Looking at the economic literature, several studies have focused on the determinants of REC or deployment and both represent the demand side (Akintande et al., 2020; Alvarado et al., 2021; Bourcet, 2020; Escoffier et al., 2021; Omri & Nguyen, 2014) offering a rich comprehension on the factors that influence the REC giving the relevant understanding of the nature and implication of RE. These determinants generally include socio-economic, political, policy, regulatory energy and environmental-related factors and provide useful insight into enhancing the REC. However, a lesser number of authors have explored empirically the factors of REP in contrast to the REC and the available studies are only limited to the specific block of countries (Aguirre & Ibikunle, 2014b; Bayale et al., 2021; Przychodzen & Przychodzen, 2020). Even though the determinants considered by the scholars either for consumption or production may be similar but may have different implications. For instance, the economies with higher GDP may have a positive impact on energy consumption and as well on production, but diverting the funds toward the construction of RE projects benefits the countries in terms of energy security.

Although few studies have explored energy production but have not vividly differentiated between energy production and energy consumption and are also limited to a certain set of countries not involving a large sample and have also included the generation from all possible sources of RE. This study has not included the energy from hydropower projects as the generation from the hydropower is quite mature and might not be termed as clean as it is considered due to its various technical and environmental concerns and this fact has also been identified in the review article by (Bourcet, 2020) by stating that hydropower has specific technical characteristics and may have different determinants compared to other RE sources as it possesses negative social and environmental repercussions and is also highly exploited in many countries, therefore, separating hydropower from RE sources might be relevant. To bridge this gap this research thus attempts to differentiate between the REP and REC and excludes the generation of hydropower from REP due to its different technical nature and environmental concerns.

Further, the empirical results obtained for the determinants of RE are not conclusive, hence the current study based on a large sample of global panel data of 133 countries as listed in table 12 is an attempt to assess the impact of the thematic determinants of the RE.

3. Methodology & Variable Description

3.1. Econometric Model Specification

The production of energy representing the supply-side phenomena has been taken as a dependent variable on the supposition that this variable truly reflects the penetration of renewables into the energy mix of each country. Further glancing over the literature review it has been noted that a limited number of studies have explored the supply-side penetration of RE into the system as compared to the demand side. The demand side represented by the REC may not reflect the actual installed capacity of the country's energy mix as in some countries the RE might be imported from other countries. The study conducted by (Bourcet, 2020) stated that RE deployment has not been measured in terms of the share of RE in the total installed capacity and the author is of the view that the selection of dependable variables matters as REPs and installed capacity represents the country's energy and industrial policies in contrast to the consumption representing the actual use of RE sources. To speed up the investment in RE projects and to enable the injection of more electrons from green technology the role of economic growth, trade openness, population growth, CO_2 emissions and energy generation from oil, coal, natural gas and nuclear technologies are important.

Therefore based on the above discussion and study conducted by (Przychodzen & Przychodzen, 2020) the following econometric model is designed to identify the determinants of REP.

$$REPit = \alpha + \beta GDP\ it + \gamma TO\ it + \delta URBPOP\ it + \eta NGEP\ it + \theta NUCEP\ it + \lambda CEP\ it + \mu OEP\ it + \pi\ CO2 + \mathcal{E}\ it \quad (1)$$

The dependent variable REPit represents renewable energy production and the independent variables GDP, TO, URBPOP, NGEP, NUCEP, CEP, OEP and CO2 represent gross domestic product per capita, trade openness, urban population, electricity production from natural gas, electricity production from nuclear, electricity production coal, electricity production from oil and carbon emissions respectively. The Ɛ it term represents the error term. The description of these variables is described in table 1.

Table 1: Description of the Variables

Dependent Variables	**Definition**	**Measurement**	**Data Source**
Renewable Energy Production	The percentage share of total energy production in GWh from RE sources including geothermal, solar, wind, waste, and biogas but excludes hydropower.	% of total final energy production	WDI (2021)
Independent Variables			
Economic			
GDP per Capita	GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for the depreciation of fabricated assets or the depletion and degradation of natural resources.	Constant of 2015 US$	WDI (2021)
Trade Openness	Sum of exports and imports of goods and services measured as a share of gross domestic product.	% of GDP	WDI (2021)
Environmental			
Carbon Emission	CO_2 emissions resulting from burning of fossil fuels.	Metric Ton	WDI (2021)
Energy-related			
Oil Source Energy Production	Energy production from oil	%age	WDI (2021)
Natural gas-based Energy Production	Energy production from natural gas.	% age.	WDI (2021)
Nuclear Energy Production	The energy produced from nuclear power plants.	% age.	WDI (2021)
Coal-based energy Production	Energy Production from coal.	% age.	WDI (2021)
Demographic			
Urban Population	People living in urban areas as defined by national statistical offices.	% of the total population	WDI (2021)

Source: Authors' Compilation

3.2. Renewable Energy Production

This study aims to ascertain the thematic determinants of REP. The production side of the energy mix representing the supply-side phenomena has been taken as a dependent variable on the supposition that this variable truly reflects the penetration of the renewables into the energy mix of each country. REP as defined in table 1 is selected as a dependent variable and the higher production for renewable sources suggests a lower dependency on non-renewable energy. Hydropower is excluded from the REP because it entails negative social and environmental impacts is also highly exploited in many countries and may undermine the actual technological progress in other RE sources.(Bourcet, 2020) also suggested excluding energy production from hydropower from other RE sources on the same grounds, therefore the same are excluded.

3.3. GDP per Capita

The inclusion of the income aspect through the representation of GDP or GDP per capita is an understanding of the link of economic growth with the development of RE. Higher economic growth is vital for the investment required in RE projects. The availability of higher income ensures the availability of the funds required to support the investment in green and clean technologies. A positive association of GDP with REP is expected. The studies conducted by (Bayale et al., 2021; Cadoret & Padovano, 2016; Marques et al., 2010; Omri & Nguyen, 2014; Przychodzen & Przychodzen, 2020) have also used this variable. Among these studies, the results are not similar, however many found a positive impact of GPD on the deployment of RE.

3.4. Trade Openness

Trade openness is included because it facilitates the transfer and sharing of knowledge and technology. This will provide ample opportunity to develop expertise in the use of RE technologies. Thus momentum in the development of RE will happen. A positive relationship between trade openness and REP is expected. (Omri & Nguyen, 2014) in assessing the impact of REC found a positive relationship for lower-income countries and a negative one for higher-income countries.

3.5. CO2 Emissions

The emissions from CO2 are used as a proxy for measuring environmental degradation. It is believed that higher emissions from the use of energy will indicate the dominance of the conventional source of energy. The annual increase in CO2 emissions as a result of electricity generation from fossil fuel-based power plants indicates the extensive reliance on fossil fuel-based power generation technology. Thus the higher the generation from the dirty fuel, the higher will be CO2 emissions. Thus the lower production from RE will give more space to non-RE causing higher CO2 emissions. Therefore, less generation from RE sources will demonstrate higher environmental degradation. A negative association between REP and CO2 is expected for this research study. Previous studies have also used this variable but the obtained results are different. For instance, the studies conducted by (Aguirre & Ibikunle, 2014; Cadoret & Padovano, 2016; Omri & Nguyen, 2014) found positive results however, the studies conducted by (Bayale et al., 2021; Escoffier et al., 2021; Marques et al., 2010) revealed a negative impact.

3.6 Urban Population

The urban population also plays an important role in supporting the installation of green and clean RE technology for energy production. It is claimed a higher urban population stimulates the installation of renewable sources and thus enhances REP energy therefore a positive relationship between urbanization with REP is expected. (Bayale et al., 2021) also used this variable and found a positive association with REP.

3.7. Energy-related Variables

Higher energy production from non-renewable sources acts as a barrier to energy generation from RE sources. Therefore, it is fundamental to assess the impact of generation from conventional sources of energy on the REP and therefore, the energy-related variables are considered. It is claimed the lobby for the utilization of fossil fuel in thermal power plants is quite active and thus discourages investment in RE projects. A negative relationship between the production of energy from fossil fuels and REP is expected. The studies conducted by (Aguirre & Ibikunle, 2014; Marques et al., 2010) on a small set sample also revealed a negative relationship.

4. Data Analysis

4.1 Descriptive Statistics

The descriptive statistics of the variables' observations, mean, standard deviation, and minimum and maximum values are reflected in table 2. The mean of REP as a percentage of total REP is 2.7% of the total energy production with a maximum value of 65.44% representing Denmark. The per capita GDP growth is 13660.56 US dollars with the highest value of 18324.6 US dollars for Monaco. The mean of trade openness as a percentage of GDP is 86.8822 (%) and the highest value of 863.1951 (%) for the Virgin Island. The average value for Urbanization is 57.056 (%) and the highest value is 100% representing Bermuda. The electricity production from natural gas has an average value of 22.58 (%) and Qatar has 100 (%) generation from natural gas. The average energy production from nuclear is 5.88 (%) and Lithuania with 87.98 (%) has the highest share of the energy mix. The electricity production from coal is 17. 22% and Botswana has 100% of the electricity production from the burning of coal. The average value of the energy production from Oil is 19.55 (%) and 100% of the energy production in Gibraltar is from Oil. Mean CO2 emission is 4.28 per metric ton and Qatar represents the highest value of 46.70 metrics per ton of CO2 emissions.

Table 2: Summary Statistics

Variables	Observations	Means	Standard Deviation	Max
REP	3,591	2.741657	6.073974	65.44374 Denmark
GDP	5,957	13660.56	20504.28	18324.6 Monaco
TO	5,373	86.8822	56.28435	863.1951 Virgin Island
URBPOP	6,656	57.05654	24.52117	100 Bermuda
NGEP	3,591	22.57779	30.0749	100 Qatar
NUCEP	3,484	5.88193	14.80172	87.98622 Lithuania
CEP	3,591	17.22606	26.6074	100 Botswana
OEP	3,591	19.5539	28.57852	100 Gibraltar
CO_2	5,535	4.284526	5.40812	47.69994 Qatar

Source: Authors' Estimations

4.2. Correlation Matrix

The correlation matrix shown in Table 3 revealed that GDP, trade openness, and urban population are positively correlated with REP whereas; electricity production from natural gas, nuclear, coal and oil are negatively correlated. CO2 emissions per metric ton are also negatively correlated with REP.

Table 3: Correlation Matrix

Correlation	REP	GDP	TO	URBPOP	NGEP	NUCEP	CEP	OEP	CO_2
REP	1.0000								
GDP	0.2114	1.0000							
TO	0.0257	0.2779	1.0000						
URBPOP	0.1208	0.6053	0.2472	1.0000					
NGEP	-0.1455	0.1363	0.1995	0.1876	1.0000				
NUCEP	-0.0200	0.2703	0.0178	0.2682	-0.1331	1.0000			
CEP	-0.0339	0.0550	-0.0930	0.0409	-0.2486	0.0773	1.0000		
OEP	0.0140	-0.2031	0.0807	-0.0578	-0.2334	-0.2315	-0.2740	1.0000	
CO_2	-0.0325	0.6891	0.2692	0.6109	0.3592	0.1653	0.1948	-0.1784	1.0000

Source: Authors' Estimations

4.3 Econometric Analysis

This study is based on panel data and thus before applying the regression analysis on pooled data and selection of any regression model, it is important to test the assumptions of the classical linear regression model (CLRM). Accordingly, the model specification test, multicollinearity and heteroscedasticity tests were conducted. The results revealed the correct specification of the model having the p-values of the hat squared higher than 0.1, similarly, for multicollinearity, the resultant variance inflator factor depicted a value lower than 5, therefore not detected. However, after applying the Bruesh-Pagan Test to check the homogeneity of the data, it was revealed that the resultant P-value is less than 0.5, thus the data is heterogeneous, and simple pooled ordinary least squared (POLS) may not provide the best estimate. Hence robust POLS is applied. The relevant results are tabulated below:

Table 4: Link Test

REP	Coefficient	Std.Error	P-values
Hat	1.06759	.0918703	0.000
Hat-Square	-.0083231	.0098294	0.397
Constant	-.0842018	.1987539	0.672

Source: Authors' Estimations

Table 5: Variance Inflator Factor

Variables	VIF	1/VIF
CO_2	2.84	0.352167
GDP	2.43	0.410870
URBPOP	1.88	0.532765
NGEP	1.69	0.591644
CEP	1.44	0.695461
OEP	1.42	0.704715
NUCEP	1.24	0.808648
TO	1.16	0.859329
Mean VIF	1.76	

Source: Authors' Estimations

Table 6: Breush-Pagan Test

Test	Statistic
Chi-Square	1297.86
Prob.	0.0000

Source: Authors' Estimations

Table 7: Robust POLS

Variables	Robust Regression
Dependent Variable: Renewable Energy Production (REP)	
GDP per Capita	.0001418***
	(.0000132)
Trade Openness	-.0005115
	(.0018687)
Urban Population	.040868***
	(.0063244)
Electricity Production From Gas	-.0306476***
	(.0033081)
Electricity Production From Nuclear	-.0554079***
	(.0065106)
Electricity Production From Coal	-.0080193**
	(.0038484)
Electricity Production From Oil	-.0062046*
	(.0037264)
CO_2 Emissions	-.3423186***
	(.0298741)
P-Value	0.000
Observations	3,095
R-Square	0.1352

Source: Authors' Estimations

Note: Parentheses having robust standard errors, ***p<0.01, ** p<0.05, * p<0.1

The results as indicated in table 7 disclosed that trade openness has an insignificant and negative relationship with REP which is against the theoretical background of this research study. It is argued that the POLS ignores the country-specific and time-based characteristics therefore, it is imperative to apply the Random Effect Model (REM) and Fixed Effect Model (FEM) of the panel data for further analysis. After applying the REM and FEM the following results as indicated in table 8 are obtained:

Table 8: Random Effect and Fixed Effect Models

Variables	REM	FEM
Dependent Variable: Renewable Energy Production (REP)		
GDP per Capita	0.000264*** (.0000172)	0.000308*** (.0000197)
Trade Openness	0.0179*** (.0031888)	0.0151*** (.0032862)
Urban Population	0.195*** (.0151089)	0.286*** (.0178419)
Electricity Production From Gas	-0.0937*** (.0074493)	-0.126*** (.0080689)
Electricity Production From Nuclear	-0.221*** (.0135271)	-0.247*** (.0145362)
Electricity Production From Coal	-0.112*** (.0095794)	-0.150*** (.0106733)
Electricity Production From Oil	-0.0700*** (.0067953)	-0.0875*** (.0071411)
CO_2 Emissions	-0.645*** (.0470186)	-0.587*** (.0523549)
P-Value	0.0000	0.000
Observations	3,095	3,095
Groups	133	133
R-Square (within)	0.3464	0.3528

Source: Authors' Estimations
Note: Parentheses having robust standard errors, ***p<0.01, ** p<0.05, * p<0.1

The results obtained from both models indicated that GDP per capita, trade openness, and urban population have a positive and significant impact on the REP whereas energy and environmental variables indicate a negative and significant association with REP. However, to select one of the preferred models from REM and FEM, a Hausman test as tabulated below in table 9 was applied.

Table 9: Hausman Test

Test	Statistic
Chi-Square	128.68
Prob.	0.0000

Source: Authors' Estimations

According to the Hausman test, the p-value is less than 0.05 therefore, the fixed effect model is appropriate and the same will be used for the final analysis. To proceed further it is also important to carry out the diagnostic tests for the FEM model.

To check the problem of heteroscedasticity in the fixed-effect model, the modified Wald test is required to be applied. The null hypothesis (H0) for this test is that there is no heteroscedasticity and the alternative hypothesis (H1) is that is a heteroscedasticity problem. If the p-value is less than 0.05 the alternative hypothesis is accepted and the null is rejected, which means that there is a heteroscedasticity problem.

Table 10: Modified Wald Test

Test	Statistic
Chi-Square	1.8e+06
Prob	0.0000

Source: Authors' Estimations

In this case, after applying the modified wald test as reflected in table 10 above the resultant p-value is 0.0000 and accordingly the alternative hypothesis is accepted which implies that there is heteroskedasticity in the data. To remove this problem the option of robust is used with the fixed-effect model and finally, the robust fixed-effect model's results are reflected below in table 11 which are the final obtained results. This final model is significant as the p-value is less than 0.005 and all the variables are also significant.

Table 11: Robust Fixed Effects Model

Variables	Global Analysis
Dependent Variable: Renewable Energy Production (REP)	
GDP per Capita	0.000308***
	(.0000731)
Trade Openness	0.0151**
	(.006462)
Urban Population	0.286***
	(.0666274)
Electricity Production From Gas	-0.126***
	(.0369069)
Electricity Production From Nuclear	-0.247***
	(.0504042)
Electricity Production From Coal	-0.150**
	(.0622397)
Electricity Production From Oil	-0.0875**
	(.0329921)
CO_2 Emissions	-0.587***
	(.1668397)
P-Value	0.0000
Observations	3,095
Groups	133
R-Square (within)	0.3528

Source: Authors' Estimations

Note: Parentheses having robust standard errors, ***p<0.01, ** p<0.05, * p<0.1

4.4. Discussion of the Results of the Robust Fixed Effect Model

4.4.1. GDP per Capita

The result indicated in table 11 shows that GDP per capita has a positive impact on REP and is also highly significant. It is indicated that a 1% increase in the GDP will boost the REP by only 0.000308%. This implies that for the development of RE projects higher economic growth plays a supporting role, but it can be argued that still, the RE projects are not receiving adequate funds. Further, it may also be argued that the pace of the development of the RE projects still needs a greater push as it may not be on the priority list of many countries around the globe. The results of this research study are consistent with studies conducted by (Bayale et al., 2021; Przychodzen & Przychodzen, 2020).

4.4.2. Trade Openness

The results obtained for this research study as tabulated in table 11 illustrated that trade openness has a positive impact on REP and is also significant at a 5% level of significance. The result shows that a 1% increase in trade openness will increase the REP by 0.0151%. This implies that an increase in trade favours the installation of RE projects by providing avenues for the transfer of knowledge and technology. The flow of expert knowledge and transfer of technology of RE from the expert countries to the other countries with open trade avenues will generate many economic activities. This, in turn, will activate the local manufacturing of green technologies in each interested country, ultimately pushing the transition towards green and clean technologies. Therefore, in pursuit of green transition, trade openness provides multiple opportunities and plays a contributing role in the overall development of RE projects. The result is consistent with the previous findings.

4.4.3. Urbanization

The impact of urbanization as indicated in table 11 is positive and significant at a 1% level of significance. The result reveals that with a 1 % increase in the urban population, REP will go up by 0.286%. Thus the higher urban population drives the REP and the results obtained are consistent with studies conducted by (Aguirre & Ibikunle, 2014; Akintande et al., 2020; Bayale et al., 2021; Escoffier et al., 2021).

4.4.4. Electricity Production from Natural gas, Nuclear, Coal and Oil

The electricity production from natural gas and nuclear has an unfavourable significant impact at, a 1% significance level and similarly, the electricity generation from coal and oil has a negative and significant impact at a 5% level of significance. The 1% increase in energy generation from natural gas will decrease the REP by 0.126%, thus acting as a barrier to the development of RE projects. Similarly, a 1% increase in nuclear energy will bar the REP by 0.247%. Nuclear energy though having less environmental consequences but due to risk-associated concerns is treated as a conventional source of energy. The results indicate that a 1% increase in electricity production from the coal and oil sources will decrease the REP by 0.150% and 0.0875% respectively.

Thus it may be argued that the self-interest of the business stakeholders involved in the business of production of electricity from conventional sources is restricting the REP. It may also be argued that the fear of loss of revenue associated with the business of non-renewable energy projects despite its negative consequence still limits the implementation of the RE projects. They continuously support the utilization of fossil and their allied power generation technologies through a strong lobby. Thus the greed of self-interest slows the pace of the transition toward a low-carbon economy. The results obtained for these variables are consistent with the studies conducted by (Aguirre & Ibikunle, 2014; Marques et al., 2010).

4.4.5. CO2 Emissions

The CO2 emission used as a proxy for environmental degradation shows a negative and significant impact at a 1% level of significance. The results indicate that a 1% increase in CO2 leads to 0.587% less REP. This implies that the higher production of electricity from the conventional source pollutes the environment through CO2 emissions and with a lesser share of REP, the proportion of CO2 will be high. The results obtained are logical and consistent with the studies conducted by (Aguirre & Ibikunle, 2014).

5. Conclusion and Policy Recommendations

Increasing the share of REP in total energy production with the help of supportive determinants responsible for the induction of RE has become a focus for researchers and policymakers over the last few years. This study conducted on the global panel consisting of 133 countries as listed in table 12 covering the data period from 1990 to 2020 is also an effort to identify the factors responsible for enhancing the REP.

The analysis carried out on the thematic factors of the REP revealed that the economic variables (GDP per capita, Trade Openness), environmental proxy (CO2 emissions), energy-specific variables (Electricity production from oil, natural gas, nuclear and coal sources) and demographic variable (urban population) are the key determinants of the REP. The economic and demographic variables support the REP whereas the environmental proxy and energy-related variables act oppositely. Therefore, the study conducted on the panel global data is helpful for policymakers and researchers in understanding the dynamics of the determinants of REP while devising a target-oriented energy policy aimed towards greener energy transition. Thus the positive relationship of REP with GDP per capita provides an avenue for policymakers to focus on economic growth through better fiscal and monetary policies with a stable business environment. The economic growth will ensure the availability of financial resources for investment in green and clean energy production technology. Moreover, the RE installation should be prioritized over the conventional projects. The countries with high per capita indeed have more resources to allocate funds to the induction of RE projects but their non-commitment to environmental concerns may not give preference to REP, similarly, the income inequality in developing countries can bar the adoption thus a holistic approach requiring the integration of socioeconomic and environmental aspects is vital for investment in RE projects.

The positive association of trade openness with REP demonstrates the importance of trade liberalization in the form of an easy and rapid transfer of green technology globally. Therefore the policymakers should also take into consideration the trade openness as a key factor supporting the production of REP. It is also important to highlight that the developed nations may be more tilted toward earning through business due to higher capital and better infrastructure in contrast to the developing countries, however, in the long run, both will gain in terms of contributing toward the carbon neutral economy of the respective nations. Thus policymakers of the developing nations should emphasise the importance of transition to the public for accepting the reality and need for green transition. Further, the demographic variable represented by urbanization also stimulates REP, therefore the availability of finances to the urban citizens as an incentive to adopt RE will also spur the demand for green energy.

On the other hand, the negative association of CO2 emissions with REP is a signal toward a decreased share of electricity production from RE sources and reflects the fact of dominancy of conventional sources of energy production, thus causing environmental degradation. Thus the policymakers should devise policies discouraging the dominancy of generation from non-renewable sources through various policy tools like imposition of taxations on dirty fuel, carbon tax, and subsidizing green and clean technologies.

Lastly in the presence of higher energy production from oil, coal, natural gas and nuclear sources, the REP will not progress in the required manner. To increase the share of RE in the energy mix, the existence of supportive energy policies and a predictable regulatory framework will be imperative for the deployment of RE and these will spur economic growth as well as improve the environment by lower CO2 emissions. The burden of procuring the expensive fuel required for the generation of electricity from the non-renewable technologies impacting the energy security issue will also be addressed through the induction of the RE project, resulting in a stable energy supply and less environmental degradation. However, it may also be the case that the countries bestowed with mineral resources may not welcome the installation of RE projects due to apprehension of losing the business associated with earning from mineral resources. Keeping in view the future where global efforts are underway towards a transition to a carbon-neutral economy through energy transition, embracing the REP is tantamount to the survival of the fittest theory. Additionally, the generation from Nuclear though environmentally conducive, however, due to higher capital cost and proliferation risk may not treated at par with REP, therefore, the RE projects should be prioritized over any other source of energy having concerns.

This study has limitations, first, a few economic, environmental, demographic and energy variables have been considered, however, future research studies can be carried out by including other thematic variables like regulatory, political and additional variables for economic, environmental and energy variables. Second, this study has considered the broad picture by considering the global panel data, wherein the country-specific impact may not be reflected, therefore, future work may be limited to the specific country. Third, the future study may also include the instrumental variable to avoid any reverse causality. Fourth this study has taken the REP from all sources excluding hydropower generation; however, future studies may explore determinants for a single source of REP.

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Disclaimer

The views and opinions expressed in this paper are those of the author alone and do not necessarily reflect the views of any institution.

Appendix:

List of Sample Countries

Albania	Costa Rica	Iran, Islamic Rep.	Myanmar	South Africa
Algeria	Cote d'Ivoire	Iraq	Namibia	South Sudan
Angola	Croatia	Ireland	Nepal	Spain
Argentina	Cuba	Israel	Netherlands	Sri Lanka
Armenia	Cyprus	Italy	New Zealand	Sudan
Australia	Czech Republic	Jamaica	Nicaragua	Suriname
Austria	Denmark	Japan	Niger	Sweden
Azerbaijan	Dominican Republic	Jordan	Nigeria	Switzerland
Bahrain	Ecuador	Kazakhstan	North Macedonia	Tajikistan
Bangladesh	Egypt, Arab Rep.	Kenya	Norway	Tanzania
Belarus	El Salvador	Korea, Rep.	Oman	Thailand
Belgium	Estonia	Kuwait	Pakistan	Togo
Benin	Ethiopia	Kyrgyz Republic	Panama	Tunisia
Bolivia	Finland	Latvia	Paraguay	Turkey
Bosnia & Herzegovina	France	Lebanon	Peru	Turkmenistan
Botswana	Gabon	Libya	Philippines	Ukraine
Brazil	Georgia	Lithuania	Poland	United Arab Emirates
Brunei Darussalam	Germany	Luxembourg	Portugal	United Kingdom
Bulgaria	Ghana	Malaysia	Qatar	United States
Cambodia	Greece	Malta	Romania	Uruguay
Cameroon	Guatemala	Mauritius	Russian	Uzbekistan
Canada	Haiti	Mexico	Saudi Arabia	Vietnam
Chile	Honduras	Moldova	Senegal	Yemen, Rep.
China	Hungary	Mongolia	Serbia	Zambia
Colombia	Iceland	Montenegro	Singapore	Zimbabwe
Congo, Dem. Rep.	India	Morocco	Slovak Republic	
Congo, Rep	Indonesia	Mozambique	Slovenia	