



Pollutant Emissions, Renewable Energy Consumption and Economic Growth: An Empirical Review from 2015-2019

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Abstract

The recent global turn on to more effective and systematic action to reduce pollution in the context of greenhouse gases (GHGs) (primarily considered to be responsible for global warming and its related adverse effects) has led to severe discussions among various institutions, organizations and scholars from developing and developed nations in respect to the potential impacts of these efforts. This research offers a review of research on the impact of Renewable Energy used and Pollutant Emissions on Sub-Saharan African countries' economic growth. Besides, the researchers reviewed 50 articles published between 2015 and 2019 in Scopus Journals. The papers are carefully evaluated based on the comprehensive recurring variables like the theoretical point of view, the economic conditions, and the analytical perspective. Nevertheless, the empirical study showed that Renewable Energy Use, Pollutant Emissions, recorded a significant impact on economic growth. Consequently, the findings of the reviewed studies have suggested an economic growth model that can direct sub-Saharan African nations to understand better and improve the Renewable Energy Use and Pollutant Emissions at their reach regarding viable economic development provisions. A proposed model is recommended for the analysis that is best suited for economic growth.

Keywords: Pollutant Emissions, Renewable Energy Consumption, Economic Growth

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1 Introduction

There is a widespread recognition of both the function of economic growth and energy, especially in empirical researches. Energy is realized globally as a source for industrial development and economic growth according to (26). Nonetheless, the energy industry acts as a commitment to growth and prosperity through its essential commodities, which function as ingredients into almost all products and services in the country (34). Alternatively, by raising wages and driving urbanization, industrialization creates a significant rise in energy used. For instance, China's energy usage has skyrocketed for over a decade by above 150 percent, and in 2010 happened to be the largest energy user around the globe, outstripping the US (The World Approximately 60 percent of Chinese people remained under the poverty threshold of \$1.25 (in PPP) in 1991, and that was worse in growing sub-Saharan Africa (excluding South Africa) even then. Throughout 2005, China's proportion dropped to 15 percent, whereas Sub-Saharan Africa's extreme poverty rates were well above 50 percent, relative to their rates throughout the 1980s.

However, this performance has resulted in the carbonization of China's economy, traditionally as unparalleled as the hundreds of millions caused by poverty. CO₂ emissions per capita had over doubled for about 2 tons' metric of per capita CO₂ in 1990 by around 5.3 tons per capita as at 2008, crushing the average of world's per capita to 4.8 and adding extra force on international attempts to bring down world's greenhouse gas (GHG) emissions (6).

Seeing as how the developed countries have experienced rapid industrialization, economic development, and growth as a result of heavy energy use for industrial and other economic activities, it all seems and indicates that developing countries will employ the same development models. As per the United Nations (3), oil, coal, and gas has driven the industrialization of the country but have also made a tremendous contribution to economic development and social well-fare. As such, power-related emissions of carbon dioxide lead to about 2 over 3 of global emissions CO₂. The overall amount of carbon emission due to the energy sector keeps rising as the global economy grows. Nevertheless, it challenges the quest for environmental protection and viable economic growth, which is given as crucial to the globe's long-term ambitions for economic and social development as a whole. Such developments eventually lead to different arguments about the importance of the rise in energy consumption, especially from non-renewable origins to developing nations' growth. When part of climate change mitigation and environmental pollution strategies, initiatives also call for the replacement of non-renewable energy sources with renewable energy. Empirical research of the interaction among renewable energies, pollutant emissions and economic growth in developing economies is therefore crucial to their short and long-run energy policies.

The African sub-region of Sub-Sahara is the world's most impoverished region and the zone with the lowest energy use between developing areas around the globe (16) and (33). Viable development is, therefore, of immense significance and appears to be a matter of great interest for Sub-Saharan Africa (SSA). Ironically, the search for sustainability includes not only the cooperation of the different sectors of the SSA countries, yet with the use of different policy instruments. This is especially essential because, apart from arguing that economic growth depends on

many determinants along with structural change, industrial development, market openness, boosting corporate environment competition, political stability, good governance, fiscal responsibility among many others; The promotion has a variety of consequences for conservation and environmental quality in particular.

Nevertheless, the concern is how these Sub-Saharan African countries will keep pace with the industrialized world despite significant and irreversible damage to the global climate system, which has now experienced severe disruption throughout the growth of the developed countries? Will SSA nations need to be encouraged to take a distinct, i.e., fewer carbon-intensive way of living than developing countries in order to provide sufficient living standards for generations to come, even though the progress is as unparalleled as it is undetermined? Does that imply that third world economies, in turn, need to calm down their aspirations to close the gap with developed nations? That is where help comes from empirical research.

2 Literature Review

2.1 Economic Growth

Economic growth is the expansion of the projected GDP or national production of a country. In other words, when the production-possibility frontier (PPF) of a country moves externally, economic growth arises. Economic growth is generally seen as the pace of per capita income or production growth (38) Economic growth theory in the 1960s consisted mainly of the neoclassical model formed by Cass (1965), Ramsey (1928), Solow (1956), Koopmans (1965) and Swan (1956). The primary feature of this model that only within recent times seen as an established theory is the property of convergence. The higher the forecast value of economic growth, the lesser the beginning amount of real gross domestic product (GDP) per capita. If, of course, all countries were all the same, apart from their primary capital resources, therefore convergence could occur in a full course; that is, poor regions would usually grow quicker per capita than rich ones. Moreover, if countries vary in numerous estimates with a tendency to save and produce babies, access to knowledge, desire to work, and government strategies, therefore, the convergence mechanism only correlates in a narrow sense. If the original per capita GDP is weak in terms of its long-term or stable position, which is, when an economy starts far below the intended level, the rate of economic growth appears to be reliable. A developing nation, for instance, which likely has a minor long-term role as its government policies, is uncertain, or its savings rate is meager would still not usually proliferate.

The convergence principle stems from the rising returns to capital in the neoclassical model. Countries with less capital per worker (about their long-term capital per worker) tend to have higher yield rates across the board levels of economic growth). Convergence is a situation since the steady-state rates of output per worker and capital depend on the tendency to save, population growth rate, and the role of functional characteristics of products that can differ across economies in the neoclassical model. Recent modifications of the model indicate the addition of cross-country variability sources, particularly government policies on national and international market failures, property rights security, and consumption expenditure rates. Capital theory in the neoclassical model could be extended fruitfully from tangible goods to include human capital like education, experience, and health (89)

Nonetheless, the apparent shortcoming is that the per capita long-run growth rate is wholly determined by an element of the level of technological progress that emerges from external factors of the model. (The long-term growth rate of production also depends on the rate of population growth, and the exogenous norm hypothesis is an added element.) Nevertheless, we finish up between an economic growth model that describes everything except long-term growth, a condition that seems to be unsatisfactory. Latest work regarding the endogenous growth model needed to provide the needed long-run growth explanation. This method, in the main, offers a philosophy of technological progress, one of the neoclassical model's basic misplaced rudiments.

Nevertheless, the presence of a theory of changes in technology in the neoclassical system is troubling, as it is challenging to maintain the traditional competitive principles. (In the sense of Ramsey, Cass, & Koopmans, these conclusions fit well). Technological advancement involves creating new ideas that are partially non-rival and thus have facets of public goods. It is fair to pursue the steady returns to scale through the standard, efficient means of production, like capital, labor, and property, for a particular technology that is, for a specific body of knowledge. However, after a while, if the quasi-rival ideas are made up of input variables, the returns to scale tend to increase. Such rising returns are in contrast with pure capitalism. Besides, the reimbursement of non-rival outdated ideas by their present cost zero marginal will not provide the appropriate incentive for the project underlying the emergence of new ideas (9) and (97) constructed models in which concepts are accidental development or project by-products, a process called learning through doing. In such models, the developments of each person directly spread into the whole economy, a system of immediate diffusion that could be feasible for technicality because the information is non-rival. (77) suggested in just the future that in this case, the competitive structure could be used to change the equilibrium level of technological advancement, but the initial rate of growth might, of course, not be ideal for Pareto. More generally, the competitive system breaks down when innovations are partially based on purposeful R&D activities, and when the inventions of a person are gradually only applied to other companies. A decentralized theory of technological advancement in this realistic setting involves necessary changes in the system to incorporate essential elements of imperfect competition.

Such principle embellishments did not come until the study of (10) in the late 1980s. Based on the work of (9), (7), (8), the early wave of new research-Romer (70), (103), (5) did not present a theory of technological innovation. Nonetheless, growth may continue forever in these models before returns on investment in an upper class of capital goods, including human capital, do not automatically decrease as economies evolve. (44) The spillovers of information through consumers and the potential advantages of human capital are part of this process, but only because they help to avoid the temptation to reduce asset returns. (90) continued to integrate R&D concepts and imperfect competitiveness into the development model, with significant contributions from (19); and (92). (15) include these models with exhibits and extensions. In these conditions, advanced technological findings from purposeful R&D operation are given, and this work is replaced by some e*post monopoly other than the lines of Schumpeter (1934).

Over the long run, growth rates will stay high if there is no tendency to term out of ideas. The rate of economic growth and

the required amount of innovative step tend, however, not to be optimal for Pareto because of anomalies related to the formation of new goods and production methods. The long-term growth level in these areas relies on government actions such as law and order enforcement, taxes, protection of patent rights, delivery of public facilities, financial markets, and global trade legislation, and other economic factors. So, by supporting the long-term rate of economic growth, the state has significant potential for good or harm. The drawback of the early versions of the hypotheses of endogenous growth is that unstable convergence is no longer expected.

Consequently, this activity is strong quantitative reliability of information for nations and regions; to regain the convergence property, it was crucial to expand the new theories. The transfer of innovation is one such development (95). Nevertheless, the discovery review applies to the pace of technological advancement in capitalist economies, and the diffusion thesis refers to the way follower economies pass these developments through emulation. In the meantime, replication appears to be cheaper than technology development; the distribution models predict a process of convergence of conditions similar to the predictions of the neoclassical growth model. This paradigm thus incorporates the long-term growth of the endogenous development models (from the discovery of innovations in modern economies) with the equilibrium quality of the neoclassical growth model. Endogenous growth theories, which include the emergence of innovations and production methods, are essential to provide possible reasons for long-term growth. The new cross-country empirical work on development has provided further support from the traditional, neoclassical paradigm as it has been extended to accommodate human capital, the flow of innovation and government policies, hypotheses of fundamental technical change tend to be the most important to explain why the world as a whole can continue to develop indeterminately per capita.

2.2 Renewable Energy

Energy refers to the material that acts with energy or drive. In other words, energy is usually given as the capacity to work or generate heat that is obtained from many forms such as burning fuel, absorbing the rays of the sun, or from the minerals below the ground of the Earth (93). From used cars to lighting plants, by driving computers to processing equipment, it is a primary tool that is inseparably linked to everyday human life, and also industrial and economic growth. Apart from all considerable amounts of energy resources, physical energy, or services. These may contain chemical energy (e.g., petroleum, natural gas, carbon, and biomass), thermal energy (geothermal deposits), mechanical energy (e.g., wind, falling water), radiation (sunlight, infrared radiation), nuclear reaction potential (uranium, plutonium) or electrical energy (electricity). We have physical bodies that differ. Crude oil, most petroleum products of gasoline, and water are liquids. Water requires energy available only by its motion: coal, most of the coal, and the solids of uranium. Natural gas and wind are in gasses, with wind-based solely on its motion, including available energy. Geothermal energy is accessible by hot water or solids (subterranean rock formations). Sunlight is a pure form of energy. Electricity comprises of electrons moving in such an electrical power (93).

In contrast, renewable energy use sources, such as light, water, wind, waves, are primarily derived from existence and are

not polluted by their being. Directive 2001/77/EC of the European Union describes renewable energy sources as non-fossil renewable energy sources that include "wind, sun, geothermal, ocean, tidal, hydropower, biomass, landfill water, sewage treatment plant fuel and biogas" (Commission, 2001). Renewable energy use has been increasingly gaining public and political interest in recent years, primarily because of its ability to lead to pollutant emission reductions. Solar energy, for example, is commonly used in many countries to generate electricity. In contrast, plant fuel is also used for geothermal, wind, water, and biomass. There are abundant sources of renewable energy use, with very low or zero carbon emissions, making them environmentally friendly. In 2010 the supply of renewable energy provided an additional 16.7% of the total final energy consumption. Of this number, an estimated 8.2% came from conventional renewable like hydro-power, wind, solar, geothermal, biofuels and natural biomass. Approximately 8.5% of overall final fuel accounted for organic biomass, which is mainly used for cooking and heating in rural areas of developing nations and could be deemed renewable. Hydropower provided around 3.3% of world final energy usage, and hydropower from a considerable base is steadily increasing. All other conventional renewables accounted for about 4.9 percent of final energy consumption in 2010, with rapid growth in several advanced and developing economies, respectively (REN21 2012). Renewable energy accounted for 2.2% of energy usage in OECD economies by 2010, compared to 0.6% to non-OECD nations (93).

The study of (92) analyze the long-term and causal relationship in a carbon system between the consumption of renewable energy, non-renewable energy consumption, and economic growth. The analysis integrates the rent of natural resources as an additional variable into the Empirical model evidence is based on a balanced form of panel data for selected EU-16 countries between the 1996-2014 annual periods. The Kao test shows a co-integration of emissions of carbon dioxide, economic growth, rent of natural resources, use of renewable and non-renewable energy. The Panel Pooled Mean Group-Autoregressive Auto Regressive Distributive Lag (PMG-ARDL) indicates a significant positive relationship.

(101) analyze the relationships in the United States, France, Spain, China, Italy, Turkey, and Germany between the development of tourism, renewable energy consumption, and economic growth utilizing annual data spanning the period 1995 to 2012. The study used an innovative model of causality in the Granger bootstrap panel. The results show that the development of tourism and economic growth in Germany are interdependent; while the development of tourism causes economic growth in China and Turkey, the opposite is exact in Spain. Causal ties between renewable energy and economic growth give credence to renewable energy growth theories in Spain and renewable energy growth in China, Turkish.

(90) examine the causality of economic growth, renewable energy use, capital, and labor in new EU member countries for the 1990–2009 period, using an approach of asymmetric test of causality and approach of lag ARDL. Empirical results indicate that for all countries studied, renewable energy use has positive effects on economic growth. However, there is only a statistically significant impact on economic growth for Bulgaria, Estonia, Poland, and Slovenia. It even supports the hypothesis of neutrality for Cyprus, Estonia, Hungary, Poland, and Slovenia while the hypothesis of conservation for the Czech Republic is present.

Bulgaria is supported by the fact that there is a causal relationship between economic growth and renewable energy consumption and the growth hypothesis, referring to the causality from energy consumption to economic growth.

(102) look at energy usage—the nexus of economic growth by separating energy use into two types of energy use, renewable and non-renewable. The study is made up of 11 MENA Net Oil Importing Countries (NOICs) from 1980 to 2012. To estimate the long-term relationship, a multivariate panel model was used, and the panel Granger causality tests were used to determine the direction of causality between variables. The empirical results provide evidence of a long-term balance relationship between real gross domestic product (GDP), use of renewable energy, use of non-renewable energy, real gross fixed capital formation, and labor force. Besides, the empirical findings of the Error Correction Model panel confirm the existence of bidirectional causality between the use of renewable energy and economic growth, and between the use of non-renewable energy and economic growth, the results support the hypothesis of feedback. Additionally, the empirical results provide evidence of a two-way (bidirectional) causal relationship in both short and long-term use of renewable and non-renewable energy that shows the replaceability and interdependence of these two types of energy sources.

(99) analyzes Turkey's short and long-term estimates and the causal relationships between economic growth, electricity consumption from renewable sources, and electricity consumption from non-renewable sources in a multivariate model in which capital and labor are included as additional variables. Using the cointegration method of the autoregressive distributed lag (ARDL), the cointegration test of Johansen, and the structural split cointegration test of Gregory–Hansen, we show that economic growth, renewable electricity consumption, non-renewable electricity consumption, capital, and labor are cointegrated. While non-renewable electricity consumption has a long-term positive effect on economic growth, renewable electricity consumption's long-term estimate at 5 percent of significance is negative but negligible.

The vector error correction model-based Granger causality test shows proof of the neutrality hypothesis between renewable electricity consumption and economic growth, and in the short run between non-renewable electricity consumption and economic growth in Turkey. In addition, the causality of Granger runs from renewable electricity, non-renewable electricity, capital and labor to economic growth as well as from economic growth, renewable electricity, capital and labor to non-renewable electricity in the long run, which supports the existence of the hypothesis of growth between renewable electricity and economic growth, and the long-term hypothesis of feedback between non-renewable electricity and economic growth.

(98) examine the relative performance on economic growth in 17 emerging economies of renewable and non-renewable energy consumption. To this end, the annual data from 1980 to 2012 were analyzed using the causality of the bootstrap panel, which enables cross-sectional dependence and country-specific heterogeneity throughout countries. In the view of renewable energy use, the results show that the growth hypothesis is only verified for Peru; the sustainability hypothesis is accepted for Colombia and Thailand; the feedback hypothesis for Greece and South Korea is found, and the neutrality hypothesis is valid for the other emerging economies. The growth hypothesis for China,

Colombia, Mexico, and the Philippines is found in the case of non-renewable energy consumption; the conservation hypothesis is verified for Egypt, Peru, and Portugal; the feedback hypothesis is only accepted for Turkey, and the neutrality hypothesis is valid for the other emerging economies.

(93) provide a detailed and comprehensive analysis of the role of renewable energy use and institutions in economic growth and the battle against CO₂ emissions across regions and income groups. The study uses annual data from 85 developed and developing economies worldwide over the period 1991 to 2012 for the statistical model. The study uses various econometric methods to achieve accurate results from panel estimates. The study findings indicate that the sub-samples are substantially heterogeneous. Overall, system-GMM and completely updated OLS results indicate that growth in renewable energy usage, respectively, has a substantial positive and negative effect on economic output and CO₂ emissions. Institutions have a positive impact on economic growth and a reduction in CO₂ emissions. The study findings suggest that both the deployment of renewable energy and institutions are essential in fostering economic growth and reducing CO₂ emissions. (75) investigate the relationship between the consumption of renewable energy and economic growth by integrating capital and labor as possible determinants of the function of production in Pakistan. This research used the model and rolling window approach (RWA) of auto-regressive distributed lag (ARDL) for cointegration in Pakistan. During the period 1972Q1–2011Q4, the analysis used quarterly data. The study of causality applied by VECM Granger causality and novel approaches to accounting. The findings indicate that all of the study's variables were cointegrated, demonstrating the long-term relationship between the variables. Besides, the use of renewable energy, capital, and labor are driving economic growth. The analysis of causality shows the effect of feedback between economic growth and consumption of renewable energy.

2.3 Pollutant Emissions

Pollutants include any pollution that contaminates the atmosphere. Green House Gases are the most dangerous pollutant to the earth's surface and are thus the main focus in research on the environmental impact of pollution. Global warming and sustainability are today's core threats. They are inseparably connected and must be dealt with together. Measures to limit and respond to climate impacts of greenhouse gas (GHG) emissions is necessary to ensure sustainability. Simultaneously, only sustainability may provide stable financial, political, environmental environments, and social that all nations need to effectively deal with climate change and construct carbon-neutral countries (93).

Coal, gas, and oil have driven the industrialization of the globe and also have contributed significantly to economic growth and standard well-fare. As a consequence, however, several two-thirds of international GHG emissions are currently accounted for by energy-related carbon pollutants, especially carbon dioxide emissions. As the world economy grows, the overall amount of CO₂ emitted by the energy industry remains high, resulting in climate change (81).

Climate change warms the world, changes weather patterns, raises the frequency of flooding and droughts, raises sea levels, acidifies the ocean, melts sea and land ice, impacts species of plants, animals and affects disease spread. Such emerging environmental changes are already exacerbating other pressures

on sustainability, ranging from habitat loss and depletion of resources to contamination of soil, air, and water (81).

(1) uses panel vector autoregression (PVAR) in combination with a system-generalized method of moment (System-GMM) to investigate the dynamic form of causal relationship between economic growth, carbon dioxide emissions as well as energy usage in 116 countries over the period 1990–2014. The empirical results of this study have established key relationships with significant policy implications using the multivariate model. The first economic growth is not to increase energy consumption at the global and regional levels. Second, economic growth has no causal effect on carbon emissions except for international and Caribbean-Latin America, but economic growth has a detrimental impact on global and Caribbean-Latin American carbon emissions. Third, the positive effect of carbon emissions is economic growth. Fourth, energy consumption has a positive effect on Sub-Saharan Africa's economic growth, while it harms economic growth, Middle East, and North Africa (MENA), Asia-Pacific as well as Caribbean-Latin America. Fifth, energy consumption in MENA positively causes carbon emissions, but in sub-Saharan Africa and Caribbean-Latin America, it negatively causes carbon emissions. Lastly, except for MENA and the global sample, carbon emissions are not caused by energy consumption. The impulse response feature shows evidence of global and sub-Saharan Africa's Environmental Kuznets curve (106). Also used Johansen cointegration, ARDL, and VECM techniques to examine the dynamic causality of Pakistan's economic growth, energy consumption, and CO₂ emissions over the period 1971–2009, and identified a bi-directional causality between energy consumption, economic growth, and CO₂ emissions.

Thus, (111) examining the effect of foreign direct investment (FDI), economic growth and energy consumption on carbon emissions in the Association of Southeast Asian Nations (ASEAN-5) of five selected Member countries, including Indonesia, Malaysia, the Philippines, Singapore, and Thailand. The study uses a model of panel quantile regression that takes into consideration individual non-observed heterogeneity and distributional heterogeneity. Also, some associated control variables are included in the model to prevent an omitted variable bias. The empirical findings show that the impact on carbon emissions of the independent variables is heterogeneous across quantiles. In particular, except in the 5th quantile, the effect of FDI on carbon emissions is negative and becomes essential at higher quantiles. Energy consumption reduces carbon emissions, with higher quantiles having the most significant impacts. Higher economic growth and population size tend to be reducing emissions among the high-emission countries. The study results also affirm the validity of the theory of the halo effect in countries with higher emissions.

However, in the ASEAN-5 countries, the study finds little evidence to support an inverted U-shaped curve. However, a higher level of trade openness may mitigate the increase in carbon emissions, especially in low-and high-emission nations. (107) are attempting to shed light on the ecological effects (CO₂ emissions) of economic growth, foreign direct investment as well as financial development among the selected ASEAN-5 economies. Based on the data from 1982 to 2014, the study used a range of empirical panel data analysis techniques that included approaches to Dynamic Ordinary Least Squares (DOLS) as well as Fully Modified OLS (FMOLS). The findings indicate that in the economies under study, both financial and economic growth and

FDI have a statistically significant long-term co-integrating relationship with environmental degradation (CO₂ emissions). It showed that economic growth, financial development and FDI in ASEAN-5 countries lead to an increase in the deterioration of the climate. The quadratic term for economic growth has harmed the deterioration of the environment EKC.

(89) investigate the nature of the Kuznets Curve for the 1992Q1-2011Q1 period in Croatia. Autoregressive Distributed Lag (ARDL) and VECM approach have been applied to fulfill the study's objectives. Results show that there is an inverted U-shape relationship between CO₂ emissions and long-term economic growth that is EKC's validity. Granger causality based on the VECM method shows bi-directional causality between short-term CO₂ emissions and economic growth and uni-directional causality from economic growth to long-term CO₂ emissions. The tests of DOLS and FMOLS demonstrate the robustness of the long-term results. Also, similar results are shown by Variance decomposition and Impulse response.

(100) analyze empirically how to reduce carbon (CO₂) emissions in Malaysia caused mainly by energy production, fossil fuel use, population density, and economic growth. The research adopted the autoregressive distributed lag-bound testing method for analyzing data for the 1971–2011 period. The study found that Malaysia's economic growth has a direct relationship with both short-term and long-term CO₂ emissions. Likewise, fossil fuel consumption and CO₂ emissions over the same timeframe have a positive relationship. It has been found that population density has positive effects on CO₂ emissions. Contrary to that, the long-term relationship between energy production and pollution activities is negative.

(97) looked at the effect of technology, and economic growth on CO₂ emissions from 1990 to 2016 for 18 developed and developing countries. The study used panel methodology capable of handling cross-sectional dependency effects: panel cross-sectional augmented Dickey-Fuller (CADF) unit root to assess the order of integration, Westerlund co-integration testing verified the co-integration of variables. In order to estimate the long-run relationship, we used panel fully modified ordinary least square (FMOLS) and panel dynamic ordinary least square (DOLS). The results show that, at all panel levels, energy consumption increases CO₂ emissions. Innovation, however, lowers G6 CO₂ emissions while rising emission levels in the MENA and the BRICS countries. The theory of the environmental Kuznets curve (EKC) is valid for the BRICS. The hypothesis of pollution haven (PHH) and the impact of pollution halo was confirmed at various panel scales.

The relationship between economic growth and CO₂ emissions in Azerbaijan is being examined by (105). The analysis of cointegration is carried out during the period 1992-2013. Johansen, ARDL, DOLS, FMOLS, and CCR approaches are used to investigate cointegration and estimate long-run coefficients in order to obtain more reliable results the study use cubic, quadratic and linear specifications and conclude that the last one is an appropriate reflection of the effect on CO₂ emissions in Azerbaijan from economic growth. The results of the different methods of cointegration are consistent and show that economic growth has a positive and statistically significant impact on emissions in the long run, which means that the hypothesis of the EKC does not hold for Azerbaijan. The income elasticity of CO₂ emissions was found to be between 0.7% and 0.8% using different methods. Also, the study finds that in less than one year, any

short-run imbalance can be changed to the long-run equilibrium direction.

3 Empirical Review

3.1 Renewable Energy Consumption and Economic Growth

The first area of research focuses exclusively on the interaction between the consumption of energy and economic growth. The primary objective of these experiments is to analyze whether energy consumption is a driver of economic growth or whether the output level dictates the energy consumption level. (40) published the first empirical researches to examine the causal link between energy consumption and production. Using a multivariate regression model and evidence from the United States for the period 1947-1974, they identified a unidirectional causality varying from consumption (measured by GNP) to energy usage, but not from energy consumption to output. This innovative research deepened interest in investigating the relationship between energy consumption and economic growth. Subsequent studies by (4) and (85) in the United States, however, showed no evidence of a particular causal link between both the two determinants. (4) cast doubt on Kraft and Kraft's results (1978) by questioning their findings' reliance on the specimen used. In the case of Japan for the period 1950 (85) found a definite causal link between energy consumption and income, reinforcing the opinion that the causality of Granger extends from energy to income. It is noteworthy, however, that (72) reconfirmed the unidirectional causality of GNP to the energy consumption initially observed by (40).

(6) studied the complex causal correlations in Saudi Arabia among energy consumption, energy prices, and economic activity based on a demand-side analysis. They use a multivariate Johansen method to co-integration and integrate carbon emission pollution as a controlling factor. The results show that there is at least a long-term relationship between energy consumption, energy prices economic growth and emissions of carbon dioxide contrast, long-term unidirectional causality varies from energy consumption to carbon emissions and economic growth, bidirectional causality between emissions of carbon dioxide and economic growth, and long-term unidirectional causality ranges from energy prices to economic growth and carbon emissions. In the short-run, causality varies from CO₂ emissions to energy usage and economic productivity and from energy prices to CO₂ emissions. Although the concept of energy-led growth is genuine, the proportion of energy consumption is limited in describing economic growth. In understanding economic growth, energy prices are the most influential factor. Therefore, steps intended to reduce energy usage and minimizing CO₂ emissions may not dramatically reduce economic growth in Saudi Arabia. Investing in the use of renewable energy sources such as solar and wind energy is an immediate need to monitor the use of fossil fuel and CO₂ emissions.

(60) studied the role of energy in economic growth from a regional point of view by estimating the total trans-log mechanism of output with human and physical resources and the use of competitive energy as factors of production within the context of growth. For the entire sample and the following related nation classes, the strength of the correlation between energy and development is analyzed: OECD, BRIC, NAFTA, East Asian, Eastern European, and EU15 nations. Results obtained show that the measured energy consumption elasticity is positive for all nation classes. BRIC countries have higher elasticity, about 0.37,

and EU15 have lower elasticity, about 0.12. Poor conservation relationships between power and capital are found for all nations, except BRIC and Eastern European countries.

(80) Investigated the causality relationships between economic growth, use of biomass energy, jobs, and resources in the United States between 1961 and 2011. Use of the ARDL boundary evaluation approach to cointegration to approximate long-term and short-term relationships between variables. Long-term and short-term estimates suggest the U.S. use of renewable energy has positive effects on economic growth. However, the Granger causality results show that unidirectional causality from the use of renewable resources to actual GDP follows the growth hypothesis.

By using the full decomposition methodology pioneered by (69) established the driving forces for CO₂ pollution related to energy consumption. The review of decomposition focuses on the four CO₂ emission factors: The influence of carbon intensity, energy output, societal impact, and economic activity. The research includes all of the Greek economy's primary competitive industries. The research spans the 2003–2013 period and is split into two sub-periods (2003–2008 and 2008–2013) to assess improvements in the impact of the variables analyzed during the economic crisis (2008–2013). The research was expanded to analyze the associated decoupling between Greece's economic growth and carbon emissions using the decoupling index.

Moreau and (57) examined the degree to which decoupling can be linked to each of these three causes and in particular, to systemic consequences, namely deindustrialization and tertiarisation, which transfers energy consumption abroad and re-imports it into goods as embodied energy. We calculate the consequences of structural changes, economic growth, and initiatives for energy consumption as well as energy expressed in trade at the degree of economic activities. The analytical approach incorporates the study of decomposition and input-output to tackle boundary situations where nominal trade surpluses exceed deficits in energy trading. With the additional challenge of low data quality per economic activity over time, Switzerland offers an acceptable example.

Our results showed that in economic activities, the share of embodied energy in imports exceeded 81% of final energy consumption. A study of energy intensities in exchange without and with embodied energy reveals that decoupling is much more artificial than actual. Moving energy-intensive operations abroad boosts domestic output but, by focusing on more implicit energy consumption, increases overall energy consumption safety. Therefore, energy metrics should be modified in order to avoid possible overlapping policy goals between energy production and safety and trade.

(96) Use the autoregressive distributed lag (ARDL) testing approach to cointegration to investigate the dynamic causal relationships between per capita CO₂ emissions, real GDP per capita, non-renewable electricity production per capita and renewable electricity production per capita, and international trade in Italy from 1960 to 2011. In the presence of potential structural breaks, the study finds cointegration among these variables and overcomes the issue of multicollinearity in research design. The concept of the Kuznets Environmental Curve (EKC) is tested analytically as the projected emissions model shows that over time, economic growth results in less pollution. Renewable electricity output per capita lowers both short-run and long-run rates of CO₂ emissions per capita, whereas international trade

only has a positive effect on long-run carbon dioxide emissions per capita. International trade Granger causes per capita emissions of CO₂ and per capita production of non-renewable electricity. However, the results show the presence of the long-term unidirectional causality of Granger, ranging from per capita output to per capita renewable electricity production, and from per capita non-renewable electricity production to per capita renewable electricity production. The findings show that the production of renewable electricity is a crucial solution over time to reduce pollutant emissions.

(94) Analyze the relationship between emissions, economic growth, and hydropower consumption over the period 1961–2013 in the various business cycle regimes of G7 countries. The research used methods of Markov Switching-Vector Autoregressive (MS-VAR) and MS-Granger Causality as traditional methods investigate causality by assuming the same degree for all periods. Such methods allow evaluating the relationship and casual dynamics between variables in various regimes, unlike traditional methods. The results of causality obtained for different regimes helped to propose policy recommendations for each regime individually. Based on the results of the study, it was found that there is a bidirectional causality between carbon dioxide emissions and economic growth in the crisis regime and the high growth regime, whereas emissions of carbon dioxide are Granger causes of economic growth in all regimes in general. The study found evidence that the consumption of hydropower resources granger causes economic growth in general, while in some G7 countries, there is a bidirectional causality. Moreover, the results of these models indicate that carbon dioxide emissions are Granger causes of hydropower consumption in the first, second, and third regimes, and hydropower consumption is Granger causes carbon dioxide emissions in some G7 countries.

(96) Analyses the long-term and causal relationship for the period 1960–2013 between CO₂ emissions, militarization, economic growth, and energy consumption in the USA. A short-run and long-run relationship between variables with a positive and statistically significant correlation between CO₂ emissions and militarization was found using the bound test approach to cointegration. MWALD and Rao's F tests have been applied to establish the causal link. The proof of a unidirectional causality ranging from militarization to CO₂ emissions, from energy consumption to CO₂ emissions, and from militarization to energy consumption has been identified without feedback according to Rao's F Tests. However, the results determined that the forecast error accounted for 26 percent of the forecast-error difference in CO₂ emissions.

(111) examine the effect of hydropower use on China's economic growth and CO₂ emissions from 1965 to 2016 empirically. Using the ARDL bounds cointegration testing method, this study confirms the presence of a long-run relationship between variables. Also, the consumption of hydropower energy has a positive impact on economic growth, while CO₂ emissions have a negative long-term impact on economic growth. Economic growth and CO₂ emissions, however, have a positive impact on the use of hydropower. The research also failed to support the hypothesis of the environmental Kuznets curve (EKC) for China. The Granger causality analysis shows a unidirectional causality from the use of hydropower to economic growth. In contrast, hydropower consumption, economic growth, and long-term CO₂ emissions have

bidirectional causality.

(109) uses the nonlinear ARDL model to examine the nexus asymmetries between energy use, pollution emissions, and real output in South Africa. The results of the estimated nonlinear ARDL model show that there are asymmetries in the relationships between energy consumption, CO₂ emissions, and real output in South Africa, both in the short and long run; the impact of positive shocks is different from that of adverse shocks. Real production is only influenced by negative energy shocks when analyzing the effect of energy use on the real output level, and this also relates to the effects of pollution emissions on real output. About the impact of energy use on pollution emissions, the findings show that CO₂ emissions are only influenced by adverse energy shocks in the long run, while both negative and positive energy shocks affect pollution emissions in the short run. As for the effect of real output on emissions from pollution, the results suggest that real output does not impact CO₂ emissions in both the short and long run, and this applies to both positive and negative performance shocks. However, the results show that CO₂ emissions do not impact energy use in the long run; this applies to both positive and negative shocks. Nevertheless, both positive and negative shocks of pollution emissions in the short run have an impact on energy use, but positive CO₂ emission shocks have a more significant impact on energy use than adverse shocks. Similarly, the results indicate that on the impact of output on energy use, output does not affect energy use in the long run, and in the short run, only adverse real output shocks affect energy use.

(103) investigate the causal relationship between energy consumption, carbon dioxide emissions, economic growth, trade openness, and urbanization for the 1992-2010 panel of new EU members and candidate countries. This relationship is tested using panel unit root tests, panel cointegration techniques, and panel causality checks. The key findings provide evidence to support the theory of the Environmental Kuznets Curve. Therefore, for the sampled countries, there is an inverted U-shaped relationship between environment and income. The findings also show that a short-term unidirectional panel exists, ranging from energy consumption, trade openness and urbanization to carbon emissions, from GDP to energy consumption, from GDP, energy consumption and urbanization to trade openness, from urbanization to GDP. As for the long-run causal relationship, the results indicate that approximate coefficients of lagged error correction time in carbon dioxide emissions, energy consumption, GDP, and trade openness equations are statistically significant, suggesting that these four variables may play an essential role in the adjustment process as the model departs from the long-run equilibrium.

(104) analyze and compare the connection between Chinese and US energy consumption, air pollution, and economic growth. These countries are the world's dominant economies, and the study analyses how energy consumption and air pollution change as the economy grows. The study used research data from 1970 to 2014, due to the availability of data from both countries, the period was determined. To investigate the relationship of long-run equilibrium, the ARDL bound test was performed. Unit root results indicated that all variables of order one are combined. The F-statistics values surpassed the upper bound value in the case of the ARDL bound test which means they were statistically significant. The results of the estimate substantiated the positive energy consumption coefficient at the rate of 1 percent significance in China, indicating that air pollution may increase

as energy consumption in China increases. The empirical results of the United States, however, are precisely the opposite. The findings of the CUSUM and CUSUMSQ tests showed that all coefficients are stable in both short-and long-run models.

Begum, (91) use econometric methods for Malaysia to examine the dynamic impacts of GDP growth, energy consumption and population growth on CO₂ emissions. Empirical results from the ARDL bounds testing method indicate that CO₂ emissions per capita decreased with increasing GDP per capita (economic growth) over the period 1970–1980; however, CO₂ emissions per capita increased sharply from 1980 to 2009 with a further rise in GDP per capita. The Sasabuchi also confirms this—Lind–Mehlum U (SLM U test) and the dynamic ordinary least squared (DOLS) tests. Consequently, during the study period, the EKC hypothesis is not valid in Malaysia. The findings also show that both per capita energy consumption and per capita GDP have long-term positive effects with carbon emissions per capita, but the rate of population growth has no significant impact on CO₂ emissions per capita. The study suggests, however, that long-term economic growth may hurt Malaysia's CO₂ emissions. Significant transition of low-carbon technologies such as renewable energy and energy efficiency could, therefore, lead to reducing emissions and maintaining long-term economic growth.

3.2 Pollutant Emissions and Economic Growth

The second work section focuses on exploring the complex impacts of economic growth, including emissions from waste. Most of the experiments from this study branch seek to check the Environmental Kuznets Curve (EKC) reliability. The EKC theory originated in the early 1990s with a route-breaking report by (29) on possible NAFTA (North American Free Trade Agreement) effects. The EKC argues that even an inverse U-shape curve reassembles the relationship between economic growth and environmental degradation. This means that the rate of emissions decreases when the nation progresses but starts to decrease once the income rises to an inversion point. If the EKC theory were valid, then economic growth will be a cause of environmental change rather than a challenge to the environment. The literature of the EKC is rich in studies examining linear and quadratic and cubic associations between pollutant emissions and per capita income.

Likewise, the findings in this field of research are also inconsistency in the researches between power and production. Many simple EKC research views environmental damage as factor-dependent and revenue as an independent. The fundamental difference between these simple EKC models was the selection of various pollutants, periods and nations. For reference, Grossman and Krueger (1992) used the GEMS dataset to estimate EKC for SO₂ (Sulfur Dioxide). It was noticed that CO₂ turning points were around \$4,000–5,000. Selden and Song (1994) calculated EKCs for four pollution series: SO₂ (Sulfur Dioxide), NO_x (Nitric Oxide), SPM (Suspended Particulate Matter), and CO (Carbon Monoxide) using longitudinal data from developing nations. The approximate touchstones in this analysis were fairly high compared with the Grossman and Krueger (1992). The watershed moment was \$10,391 for SO₂; \$13,383 for NO_x; \$12,275 for SPM; and \$7,114 for CO₂.

Generally speaking, this study showed that pollution switching points are likely to be higher than for atmospheric concentrations (2) check-in sections of nations for the Granger causality among income and carbon emission using panel data. Their findings

suggest that causality varies from income to pollution, or no strong association occurs in developing nations, whereas causality ranges from emissions to wealth in advanced nations. Many EKC experiments also include external explanatory variables for modeling underlying or similar influences such as "political freedom" (8) exchange (52).

Although many experiments are examining the presence of EKC, the evidence suggests that there is no mutual agreement to accept the existence of a U-shaped curve. Nonetheless, it is worth noting that local pollutants (e.g., SO₂) are much more likely to show an inverted U-shaped wealth association than common pollutants such as carbon dioxide. Such research is also consistent with the principle of environmental economics because local effects are internalized within a particular society or country and are likely to result in environmental policies to address emissions externalities before such policies are extended to internationally externalized problems (4).

3.3 Renewable Energy Consumption, Pollutants, and Economic Growth

The fifth most recent research division integrates the relationship between energy consumption and environmental pollution economic growth into one system and analyses it using modern econometric methods concurrently. The research continues with the work of (3), who provided proof of an asymmetric impact on the American economy with oil price fluctuations. The finding indicates that price increases may be associated with decreases in economic activity, but price falls do not indicate a distinct correlation with the market. In contrast, (45) addressed that a change in oil prices is likely to have a more significant impact on economic growth in an atmosphere where energy prices have been stable than in an area where motion in oil prices has been volatile and constant. They employed GARCH (1, 1) and 1949:3 to 1992:3 test duration and observed that positive uniform shocks have a significant impact on economic growth, but harmful standardized shocks are not.

Interestingly, however, in 24 Countries in Africa, (12) explored the nexus between economic growth and energy used. They implemented the methods of Panel ARDL between 1982 and 2011. They reported that the parameters are co-integrated and also have long-term relationships. Energy consumption impacts economic growth substantially, but CO₂ emissions have a significant influence on economic growth. The Granger causality analysis showed that perhaps the causal link between CO₂ production and economic growth is bidirectional, whereas the unidirectional correlation extends from economic growth to energy usage. Co-integration and Granger causality methodology applied by (7) to investigate the correlation between economic growth and energy consumption in ASEAN-5 nations viz; Indonesia, Philippines, Malaysia, Thailand, and Singapore. They employed a time series covering the 1980-2012 era. The empirical findings showed two associations of co-integration between factors in Thailand and the other in the countries involved.

(98) used bootstrap sliding window causality approaches to analyze the connection between economic growth and the use of nuclear energy (NEC) in G-6 nations. His experimental results showed no causality among NEC and economic growth in all nations, but a two-way causal link between NEC and economic growth was observed in Germany. He also stated that nuclear energy use is more effective than Japan, Germany, and the United Kingdom in terms of economic growth in Canada, France, and the

United States. Nevertheless, (13) employed equilibrium bootstrap to explore the causal nexus here between carbon dioxide factor and Malaysia's economic growth between 1975 and 2013. Their results showed a one-way causality from energy consumption to carbon dioxide both in the bi-variate model and the multivariate system.

Likewise, (16) analysed the causal structure and equilibrium relationship between Jordan's financial creation, energy consumption, and economic growth. During the time 1976-2010, he used ARDL methods. His result suggested that there was a lengthy-term linkage between economic growth and its predictor. He has observed a two-way causal relationship between CO₂ pollution and economic growth and one-way causality spanning from energy consumption to economic growth and foreign direct investment to economic growth. In Malaysia, (109) are also investigating the effect of urbanization on energy consumption during the period 1970Q1-2011Q4. Their study documented the presence of a long-run relationship between the parameters. Capitalization, Urbanization, economic growth, and trade openness have positive significance control on energy used. The analysis of the causality showed a one-way causal linkage running to energy used from urbanization.

Furthermore, (75) employed ARDL, VECM, and Rolling Window techniques to analyse the linkages among renewable energy used and economic growth in Pakistan. They applied the time series of quarterly data for the period of 1972Q1-2011Q4. Their empirical results found that all variables are co-integrated and revealed the long-term correlation between the variables. Renewable energy, capital, and labor are also driving economic growth. The causality of Granger showed the influence of feedback between economic growth and renewable energy. (109) analysed the relationship between energy consumption, economic growth, CO₂ pollution and financial progress using Portege's annual data from 1971 to 2011. The outcome of co-integration showed a significant positive correlation between CO₂ pollution and economic growth as well as adverse effects between financial stability and economic growth. Granger causality test shows bidirectional causality between heat consumption and CO₂ production, and there is unidirectional causality from economic growth to energy usage.

(21) examined the relationship between China's economic development, urbanization, and energy usage. They find that both urbanization and economic growth have a positive effect on energy consumption growth, rapid economic growth, and urbanization. Moreover, for the period 1991-2012, (93) analysed the effects of renewable energy use and economic growth in 38 countries. The board introduces co-integration and causality. We confirmed the existence of long-term co-integration between the variables. The consequence of the causality of Granger demonstrated unidirectional causality from the use of renewable energy to economic growth. While in 1980-2008, (12) studied the impact of carbon dioxide, energy consumption and pollution on ASEAN-5 economic growth. We also introduced a new smooth transition regression method board technique. We observed that either the first or the second regime's energy consumption contributed to higher CO₂ emissions. The first regime raises the loss of the climate in economic growth while the other policy reversed the trend.

Also, for the period 1990- (3) analysed the nexus relationship between carbon emissions, energy consumption and economic growth in 58 countries. They find that GDP per person and energy

consumption in all countries has a positive effect on coal. While climate change and other effects more severe than other environmental issues, the effect of economic growth on the climate has gained increased attention. (41) have studied the association in Vietnam from 1971–2011 between financial progress, capital stock, energy consumption, and economic growth. Our results showed that economic growth has positive effects on financial development, capital stock, and energy consumption. We also found a causality unidirectional to economic growth from energy consumption.

(88) analysed the complex interconnectedness in the energy output nexus by extending panel vector auto-regression (PVAR) and impulse response mechanism analyses to data on energy consumption (and its sub-components), greenhouse gas emissions and real GDP in 106 countries categorized by different income classes over the period 1971–2011. Our results show that the impacts of different types of energy usage on economic growth and pollution are heterogeneous for different groups of nations. In contrast, the causality between total economic growth and energy consumption is bidirectional, giving rise to the theory of feedback. Finally, they find, however, in examining the argument for an inverted U-shaped EKC, that the current development cycle aggravates the trend of greenhouse gas emissions. We cannot provide proof in this respect that developed nations can probably grow out of pollution.

The study of (9) explored the ties between the use of renewable energy, international trade, oil prices, and economic growth. This seeks to analyse these complex relationships using the boundary check approach to co-integration and the Tunisian ARDL technique for the period 1980–2011. Our results showed a bidirectional interaction in the short run between the use of renewable energy and international trade. Indeed, a rise in oil prices would lead to an increase in the use of renewable energy. In contrast, a unidirectional correlation between the use of renewable energy and the oil price is shown in the short run.

In contrast, (61) implemented the embodied (direct plus indirect) greenhouse gas (GHG) emissions from 2000 to 2013 to gain Macao's decoupling markers. The results showed that Macao's economy had undergone four decoupling stages, with a distinct trend towards substantial decoupling. Some discrepancies can be seen when comparing TEGE's decoupling metrics in terms of formal accounting with that of direct accounting. To respect to total energy consumption (TEC), the TEC of Macao has decoupled from its economic growth. Nevertheless, the energy-related emissions of GHG are strongly linked to TEC. Based on the decoupling performance, energy-saving and pollution management initiatives can be established for Macao. This dissertation is the first analysis of Macao's degree of decoupling.

Likewise, by disaggregating energy use into two types of energy usage, renewable and non-renewable power, Kahia, (102) explored the energy use of economic growth nexus. Our analysis is made up of 11 MENA Net Oil Importing Countries (NICs) from 1980 to 2012. They used a multivariate panel model to approximate the long-term relationship, and the Granger panel was used to determine the course of causality between variables. Their results showed the long-term equilibrium of real gross domestic product (GDP), the use of renewable energy, the use of non-renewable energy, real gross fixed assets, and the labor force. The findings also provide evidence that elasticities are optimistic and statistically significant. In contrast, the results of the Error Correction Analysis committee confirmed the existence of

bidirectional causality between the use of renewable energy and economic growth, and between the use of non-renewable energy and economic growth. Their results provided evidence of a two-way (bidirectional) causal relationship in both the short and long-term use of renewable and non-renewable energy, which illustrates the replicability and interdependence between these two energy sources. Also, (77) investigated the relationship between renewable energy use and economic growth in 9 Black Sea and Balkan countries as part of the traditional output mechanism for 1990–2012. To this end, we use co-integration panel (62) co-integration approximation approaches (63) and various panel causality inference techniques (14). Their study found that the long-term equilibrium between the use of renewable energy and economic growth and the export of renewable energy has a positive effect on economic growth. The findings of the different causality panel support development hypotheses in Bulgaria, Serbia, Macedonia, Russia, and Ukraine; input hypothesis in Albania, Georgia, and Romania; neutrality hypothesis in Turkey and results support feedback hypothesis based on the panel data set including all nine states. The results suggested that renewable energy use has a significant impact on economic growth in the Balkan and Black Sea nations.

(59) have explored whether the effect of renewable energy has stabilized the nation's economic growth prospects. To achieve this, data from the 1971Q1 to the 2013QIV quarterly time series were used. The study used the detrended systemic break experiment Clemente Montanes-Reyes, the co-integration test, together with the Bayer-Hanck test and the ARDL secondary analysis approach to co-integration. Therefore, the study of causality was performed using the causality model of VECM Granger. The findings verified the co-integration of the variables. The results revealed that renewable energy use in Germany consolidates the economic growth opportunities of the country to the point that a 1% rise in the consumption of renewable energy improves German economic growth by 0.2194%. Therefore, an increase of 1% in capital leads to an increase in the economic growth of 1,1320%, while an increase in the economic growth of 0.5125 percent was due to an increase in labor productivity of 1 percent.

On the other hand, the causality analysis revealed that there was a feedback effect between the use of renewable energy and economic growth. While there is a bidirectional correlation between renewable energy use and resources, the same connection has been made between capital and economic growth. Their research suggested clear strategies to help prevent, among others, the collapse of the renewable energy industry locally and internationally. (23) also used panel data from 210 countries between 1960 and 2014 to examine the relationship between economic growth, electricity consumption, oil prices, total fixed capital investment, and population. Together, they used oil and electricity prices to test the highly predictive economic growth observer. Besides, the data are divided into employment, OECD, regional level, level of renewable energy use, and oil exports/import nations. Pedroni system co-integration, completely updated OLS, and panel vector error correction test was used to evaluate the co-integration, short-term and long-term relationship among variables. The full panel results demonstrate a two-way relationship between electricity consumption and GDP, oil and GDP costs, fixed capital development, population, and GDP. Furthermore, the findings indicated that countries using non-renewable sources to generate electricity, such as coal and

oil, had a negative relationship with economic growth in the electricity usage of these nations. Also, the results differ by level of income, OECD and national use of renewable energy.

4 Conclusion

Although the course or frequency is not explicit, it can be inferred based on published research that substantial evidence supports the theory of bidirectional or unidirectional causality between economic growth and energy consumption, particularly renewable energy use. As many experiments exploring the causality between the two factors provided contradictory findings, data on the pollution and economic growth nexus are usually inconclusive. Causality orientation has significant policy consequences as understanding the course of causality has direct implications in influencing the energy conservation and subsidy system of government policies. Given that there is unidirectional causality extending from economic growth to energy consumption, energy efficiency policies should have almost no or adverse effects on a nation's economic growth. Those results can then be used by politicians to reduce the tax burden and stimulate savings or enhance government spending. On the other hand, if unidirectional causality occurs from energy consumption to economic growth, the government should use extra resources to subsidize energy prices and ensure long-term, sustainable sources of energy for its economy. In a given scenario, reducing energy usage may lead to a fall in employment and income, for example, by taking domestic energy costs into line with market prices.

Ethical issue

Authors are aware of, and comply with, best practice in publication ethics specifically with regard to authorship (avoidance of guest authorship), dual submission, manipulation of figures, competing interests and compliance with policies on research ethics. Authors adhere to publication requirements that submitted work is original and has not been published elsewhere in any language.

Competing interests

The authors declare that there is no conflict of interest that would prejudice the impartiality of this scientific work.

Authors' contribution

All authors of this study have a complete contribution for data collection, data analyses and manuscript writing.

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