Bulletin of Business and Economics, 12(4), 409-418
https://bbejournal.com
https://doi.org/10.61506/01.00140

Green Growth, Environmental Quality, Energy Consumption Nexus in OECD Countries

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Abstract
Sustainable economic development is desirably terrible for improving social welfare. It implies that economic development should not be at the cost of environmental degradation, but rather environmental sustainability should be maintained. This study has examined the green growth, environmental quality, and energy consumption nexus in 38 OECD countries using panel data from 1991 to 2020. We have estimated two models. The first model explores the impact of green growth on environmental quality and the second model probes the link between non-green growth and environmental degradation. For this purpose, the ARDL technique has been used to estimate the results. Green growth has not followed the environmental Kuznut Curve theory while Non-Green growth has validated the environmental Kuznut Curve theory. Furthermore, Environmentally friendly technological innovation, renewable energy consumption, environmental-related tax, and human capital turn out with negative signs while foreign direct investment and trade openness are positively related to environmental degradation. The study also suggests policies to decarbonize or minimize the emissions in the economies.
Keywords: Green Growth; Non-Green Growth; Environmental related Tax; Renewable Energy Consumption; Panel-ARDL

1. Introduction

The green economy is beginning to take shape as a concept that offers the necessary economic adjustments to achieve environmental sustainability, even though the world can produce and consume products and services in accordance with their biological potential. Given the state of the global economy, national and international players have long raised concerns about the idea of a "green economy" (European Commission, 2010a; Organization for Economic Co-operation and Development (OECD, 2011). For instance, the estimated cost of welfare losses resulting from environmental pollution is 6.8% of the world's gross domestic product (GDP) (Landrigan et al., 2018). According to estimates, the welfare cost of preventable deaths from air pollution is 3.6% of GDP (OECD, 2017).

All these disadvantages, however, compel us to recognize that green growth is possible and that it advances economic development while protecting the world's natural resources. The widely acknowledged development phenomena have a new facet thanks to the green economy, which is acknowledged as a crucial component in the effective use of energy and natural resources, the reduction of carbon emissions, and the preservation of biodiversity. Given this, it is reasonable to argue that the green economy, with its aspects including the social, economic, and environmental spheres in addition to the GDP—which has traditionally been regarded as a stand-in measure of economic development—has produced new focus points (Nahman et al., 2016). The World Commission on Environment and Development (WCED) in England delivered the report "Our Common Future," which included economic activity with environmental challenges for the first time on a global scale.

The focus of this new understanding, which went by the tagline “A global agenda for change,” was on international and national collaboration in support of environmental goals that guarantee sustainable development. Many growth indicators for the shift to a green economy have been found in recent years, and several useful worldwide publications on green growth have been released. The idea of “green growth,” which is framed within the context of these initiatives, promotes the adoption of low-carbon and clean energy technology. Additionally, it promotes economic growth by lowering the expenses associated with environmental disasters, shortages of raw materials, and other related circumstances. Analyzing the GDP share in green growth—which is widely acknowledged as the fundamental indicator of a nation's economic development—is also crucial (Janicke, 2012; Audi et al., 2023). It is anticipated that this study will contribute to the understanding of green growth dynamics by illuminating the connection between green growth indicators and GDP as a gauge of economic advancement within the context of environmental sustainability.

When it comes to ecological modernization, the phrase “green economy” is new. This vocabulary, which dates back to the 1970s, is acknowledged as a requirement for the sustainable development that the globe requires (Lorek and Spangenberg, 2014). The core idea of the green economy concept, “green growth,” refers to a cleaner, resource-efficient policy issue with sustainable consumption and production (Hallegatte et al., 2012). This political issue raises revenue as well as natural capital, which is the input of the production function. As a result, it makes it possible to pursue a successful strategy in the fight against environmental, economic, and green growth issues as we move the planet into a sustainable orbit. These days, it can be said that environmental risks brought about by altered ecosystems and weather patterns for society, particularly in light of the impoverishment of households in developing and underdeveloped nations and the economic hardships they face, are causing humanity to undergo a global transformation. At this time of global transition, the OECD’s Green Growth Indicators report is a highly helpful resource on green growth, which encourages a nation's growth and development while protecting its natural resources (OECD, 2017).

To track nations' advancements within the green growth threshold, several green growth indicators were developed. Environmental and resource productivity, natural asset base, quality of life in the environment, economic opportunities and policy responses, and socioeconomic context are the five categories that these indicators essentially fall under. The references to these five groups define the green growth indicators, which convey the environmental, social, and economic aspects of sustainability. Through national and international efforts, all of these conditions—defined in several disciplines—share the goal of enhancing human well-being and preventing environmental harm. However, challenges arose in the fulfillment of the green development idea due to the lack of a legally enforceable foundation or an efficient implementation mechanism.

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It may be concluded from this circumstance that the sustainability requirements established in the past have not been entirely met as of this writing. For instance, poverty still exists today in various shapes and sizes (Bouzarovski and Petrova, 2015). In a similar vein, insufficient steps are being taken to manage natural resources and adapt to environmental circumstances (Chapin et al., 2010; Audi et al., 2020).

The global ecosystem has crossed a critical barrier, and people's harmful actions in the world dynamics have made it clear that all nations in the world urgently need to pursue green growth. Despite the notion of green growth's established normative significance for all nations in the globe, its flexible nature makes it challenging to implement green growth with a consistent assessment methodology. Numerous studies assessing the green growth performances of different nations have been published in recent years, offering recommendations for different approaches. As a result, wealthy nations have created policy plans for renewable energy sources. Every nation may achieve green growth with the support and guidance of international governments and non-governmental organizations. The nations' (a) economic growth, (b) social inclusion, and (c) environmental sustainability will all benefit from this research. These components are regarded as one of the green growth indicators and are referred to as the three primary pillars of sustainable development.

The "green economy" is an economic concept that seeks to achieve environmental sustainability by aligning production and consumption with the world's biological carrying capacity. (Altenburg and Assmann, 2017; Ali et al., 2022). The term "green economy" has just developed in terms of ecological modernization. The concept of sustainable development, which may have emerged in the 1970s, continues to be viewed as an integral part of our environmental protection. (Lorek and Spangenberg, 2014). In the green economy, "green growth" is the key goal. It emphasizes the need for resource-conserving consumption and environmentally friendly industrial products. (Hallegatte et al., 2012; Audi and Ali, 2023).

Politics increases income while increasing the natural capital input to production. Therefore, it is possible to lift the Earth into a sustainable orbit while addressing environmental and economic concerns. (Kocak, 2020). Climate change, caused by carbon emissions, is triggering growth in dangerous weather events, such as famines, overflows, and warmness breakers, which need the government to intensify its efforts to combat them. We might be able to clean up the air and water with growing economic development. (Song et al., 2020; Audi and Ali, 2023). Reducing carbon emissions is far more challenging with current technologies compared to other general pollutants. Carbon emissions are far more difficult to reduce with current technologies than other general pollutants. When pollutants such as wastewater, gas, or smoke are considered, the EKC (Environmental Kuznets curve) is believed to emerge. Economic development may enable us to clean up the air and water. Using microbial decomposition and chemical reactions, sewage treatment facilities can clean wastewater, while thermal power plants can reduce air pollution by removing dust, desulfurizing, and denitrifying.

However, carbon dioxide is not included in the EKC. A large-scale application of the emission reduction technique is not currently possible due to the irreversible nature of CO_2 once it has been released into the atmosphere (Song et al., 2020). Pollution and environmental degradation have been noted as hot topics in economic development. Deterioration of the environment adversely affects limited resources and prevents poor-quality human capital from contributing significantly to total production (Azam et al, 2016; Ali et al., 2023). In general, carbon dioxide (CO_2) and methane (CH_2) are the main contributors to the greenhouse gas emission inventory (Sehrawat et al., 2015). It has been demonstrated in many studies that CO_2 emissions are negatively correlated with economic growth. Numerous scholars have demonstrated a connection between CO_2 emissions and economic growth, but no such statement has been made (Adebayo, 2021).

Human progress depends on energy, a fundamental component of all aspects of our lives. Energy production and consumption are essential to economic development. Ecological economists believe that energy is a key driver of economic development and plays a significant influence in the growth process (Ahmed and Azam, 2016). The fossil fuels being used to generate energy increases ecological and carbon footprints, which lowers environmental quality (Ahmed et al., 2022). However, they are also responsible for a wide range of adverse environmental and human welfare effects. These include climate change and the rise in global temperatures caused by increased greenhouse gas emissions. Global warming, water pollution, and land pollution are all results of using energy from fossil fuels and coal. In light of this, renewable energy is viewed as a fantastic alternative strategy for resolving the issues raised in connection to the environment and people's quality of life (Ali et al., 2023). In regards to environmental sustainability, renewable energy is viewed as a way for a country to achieve many objectives, such as improving energy access, reducing air pollution, and improving the environment. These objectives benefit not only the economy but also the environment and the living standards of a nation's people (Huan and Hong, 2020). Renewable and alternative energy (clean energy) sources like wind, solar, biofuels, hydro, and others are the foundation for the energy transition to a low or zero dioxide and sustainable energy system (Khan et al., 2022).

There are several factors contributing to these effects, including population growth and deforestation (Litavcova and Chovancova (2021). Agricultural and industrial production is dependent on energy, which also increases emissions of CO_2, nitrous oxide, and methane. Since fossil fuels generated 82 percent of the world's energy in 2015, they are becoming an increasingly significant source of energy. According to the IEA, this ratio has remained unchanged for the past 40 years. This problem can be effectively addressed by alternatives to non-renewable energy sources, such as renewable energy sources (Khan et al., 2022). Researchers believe that the nexus between environmental quality and economic expansion may be resolved by substituting cleaner energy for fossil fuels. Numerous studies have observed the influence of renewable energy on economic success. We believe that using renewable energy instead of non-renewable energy during production will reduce carbon emissions while substantially impacting output. The use of renewable energy promotes sustainable economic growth while reducing the adverse environmental effects of carbon-intensive energy sources. (Sohag et al., 2021). It has been demonstrated that renewable energy-related technologies can be combined to form

both established and innovative energy technologies (Ashiq et al., 2023). Using renewable resources should not harm the environment. Renewable energy is essential for sustained economic growth (Anser et al., 2021).

2. Review of Assorted Studies

There are many studies in which the performance of environmental quality of developed and non-developed countries has been discussed. These studies show the impact of various factors such as energy consumption, green growth, technological innovation, environmental-related tax, GDP, Foreign direct investment, and trade openness on environmental quality in different countries of the world during different periods. Table 1 shows the summary of assorted studies. We have divided this table into four sections.

Table 1: Summary of Assorted Studies

Author(s)	Dependent Variable	Data	Methodology	Variables	Results
Studies on Energy Consumption and Environmental Quality					
Kartal (2023)	CO_2 Emission	1973-2022	ARDL, DYNARDL	Energy Usage, CO_2emissions, Renewable Energy Consumption	Energy usage significant with CO_2emissions while Renewable Energy Consumption -ve with CO_2emissions
Paramati et al (2022)	Energy Consumption	190-2014	Cross Sectional Dependence Test (CD)	Environmental Technology, GDP, Financial Development, Trade Openness,	Trade Openness, Environmental Technology _ve
Adebaya (2021)	Environmental Degradation	1970-2015 In Japan	FMLOS, DOLS	Urbanization, Clean Energy, Trade Openness	Urbanization, CO_2 Emission, Globalization trigger effect on Economic Growth, Trade Openness have no significant linkage but positive association with Economic Growth due to one-way Causality
Alharthi et al (2021)	CO_2 Emission	1990-2015 MENA Middle East North Africa	EKC Employment Kuznets Curve, Quintile Technique	Renewable Energy Consumption, Non-Renewable Energy Consumption	Renewable Energy Consumption has significant impact but it reduces the level of Emission if high quintile the impact will also increase Non-Renewable Energy Consumption increases the CO_2 Emission and also size decrease with complex quintile
Anser et al (2021)	Environmental Degradation	2003-2017 Of South Asian Countries	Granger Cointegration Technique, PVECM	Renewable Energy, Green Development, Gross Domestic Product	Renewable Energy effect Green Development in long time period, while Renewable Energy and Gross Domestic Product have positive association with environment
Studies on Economic Growth and Environmental Quality					
Khan et al. (2023)	Environmental Quality	1990-2020	MMQR	Human Capital, Green Growth, CO_2 Emissions	Green Growth, Human Capital -ve with CO_2 Emissions
Khurshid and Deng (2021)	Environmental Quality	2000-2016 Cross-Sectional Data	OLS, FMOLS	Energy Utilization, Technological Innovation, Renewable Energy Consumption, Environmental Related Tax	Energy Utilization, Technological Innovation Damage Environment, Renewable Energy Consumption Environmental Related tax positive impact on Green Growth.
Sohag et al (2021)	Environmental Degradation	1980-2016 OECD Countries	CS, ARDL approach	Renewable Energy, Technological Innovation, Green Growth, Real Interest Rate	Real Interest Rate put -ve impact on Green Growth while Renewable Energy, Technological Friendly Innovation and Green evolution have Positive
Farooq et al (2021)	Environmental Degradation	2000-2016 Panel Data Of 10-Year Asian Countries	GMM	Real Investment, Carbon Tax, Green Growth Renewable Energy	Carbon Tax put Negative on Investment while Green Growth and Renewable Energy put positive on Investment, moreover, Green Environment positively related with Industrial Investment
Yang et al. (2021)	CO2 Emissions	1990-2019	DOLS, EKC	Globalization, Renewable Energy Consumption, Green Growth	Globalization, Renewable Energy Consumption, Green Growth put _ve
Sehrawat et al. (2015)	Environmental Degradation	1971-2011	ARDL Bound Test, Co-Integration, ECM	Financial Development, Economic Growth, Energy Consumption, Urbanization	Financial Development, Economic Growth, Energy Consumption, Urbanization +ve and significant
Studies on Energy Consumption, Economic Growth and Environmental Quality					
Khan et al (2021)	CO_2 Emissions	1972-2017	FMOLS	Globalization, Energy Consumption, Growth	Non-Renewable Energy + ve and significant, according EKC Economic Growth -ve and +ve

Bhat et al (2021)	CO_2 Emissions	1990-2014	Quantile Technique	Energy Consumption, Economic Growth, Urbanization, Bio Energy Use,	Energy Consumption, Economic Growth, Urbanization positive bio Energy Usage _ve and significant
Litavcova and Chovancova (2021)	CO_2 Emissions	1965-2015	Co-Integration	Energy Consumption, Economic Growth	Energy Consumption, Economic Growth significant and positive in SR
Sen (2020)	CO_2 Emissions	1972-2017	Co- Integration	Energy Consumption, Economic Development	Energy Consumption -Ve and significant with Environmental Quality, Economic Development improves Environmental Quality
Musibau (2020)	Environmental Quality	1981-2014	EKC ARDL	Gross Domestic Product, Energy Usage	Gross Domestic Product, Energy usage -ve
Khan et al (2020)	CO_2 Emissions	1965-2015	ARDL	Energy Consumption, Economic Growth	Energy Consumption, Economic Growth + ve while renewable Energy Consumption - ve in LR
Studies on Energy Consumption, Industrial Growth, Trade, Tax Burden Green Growth and Environmental Quality					
Abbasi et al (2021)	CO_2 Emissions	1972-2018	ARDL Approach	Energy Consumption, Industrial Growth, Urbanization	Economic Growth and Industrial Growth have positive impact on CO_2 while Urbanization positive and significant
Arif et al (2020)	Environmental Degradation	Panel data 1980-2018	ARDL Auto Regressive Distributive Lag	Financial Development Trade Openness	Financial Development has positive and significant impact in long time period and short time period on Economic Growth while Trade Openness put optimistic and significant impact on Environmental Quality
Amoah (2020)	Energy Consumption	1996-2017 Panel Time Series Data of Africa	FMLOS, DOLS, OLS	Renewable Energy, Tax Burden, Trade Freedom	Renewable Energy and property rights have negative impact on Energy utilization while tax burden put positive and significant impact with Sustainable Development.
Wang and Shao (2019)	Environmental Degradation	2001-2015	Panel Threshold Technique	Formal and Non-Formal Market Base Environment Technologies, Education Infrastructure and Transport	Technologies put positive and significant impact on Green Growth while high level Technologies, transport, Infrastructure put negative and insignificant Expenditure put positive

This section consists of reviews in which we have analyzed the different studies related to green growth, energy consumption, and environmental quality in the context of Middle Eastern and South Asian developed and less developed countries. So, we divide it into three sections. In the first section, we have reviewed different studies related to energy consumption and environmental quality. We have found mixed results by using Granger causality, FMOLS, EKC, and ARDL techniques. Some studies have found a negative association between energy consumption and environmental degradation. The result of nonrenewable energy consumption is significant, negatively related to green growth, and increases the level of emissions, while renewable energy consumption has a significant impact and also reduces the level of emissions. Moreover, technological innovation and clean energy improve environmental quality. In the second section, we have reviewed a few studies related to green growth and environmental quality. We have found a positive association among technological innovation, renewable energy consumption, environmental-related taxes, and green growth. These variables play a vital role in world sustainability. Furthermore, some studies look into how reducing energy consumption can improve green growth and lower emissions. Even some studies show a negative relationship between GDP and environmental degradation in both developing and developed countries.

In the third section, we have reviewed the studies of energy consumption, economic growth, and environmental quality. Using the ARDL, Co-integration, EKC, and FMOLS techniques, we discovered mixed results, with some studies indicating a positive relationship between energy consumption, economic growth, urbanization, environmental quality, and environmental harm. While, other variables such as renewable energy consumption, urbanization, and trade openings are negatively related to the environment and are also helpful in the reduction of CO_2 emissions. In the fourth section, we reviewed the studies of energy consumption, industrial growth, trade openness, tax burden, green growth, and environmental quality. Some variables, such as tax burden, trade openness, urbanization, globalization, and industrial growth, also have a positive impact on CO_2 emissions. Technologies and transport infrastructure have a negative relationship with CO_2 emissions.

3. Model Specifications, Data and Methodology

The linkage among green growth, energy consumption, and environmental quality is established with the help of the following two models:

Model 1: Environmental Quality with Green Growth

$$CO_2 = f(GG, GG^2, EFTI, REC, ET, HC, FDI, TO) \quad (1)$$

$$CO_{2it} = \alpha_0 + \alpha_1 GG_{it} + \alpha_2 GG^2_{it} + \alpha_3 EFTI_{it} + \alpha_4 REC_{it} + \alpha_5 ET_{it} + \alpha_6 HC_{it} + \alpha_7 FDI_{it} + \alpha_8 TO_{it} + \mu_{it} \quad (2)$$

Model 2: Environmental Quality without Green Growth

$$CO_2 = f(GDP, GDP^2, EFTI, REC, ET, HC, FDI, TO) \quad (3)$$

$$CO_{2it} = \alpha_0 + \alpha_1 GDP_{it} + \alpha_2 GDP^2_{it} + \alpha_3 EFTI_{it} + \alpha_4 REC_{it} + \alpha_5 ET_{it} + \alpha_6 HC_{it} + \alpha_7 FDI_{it} + \alpha_8 TO_{it} + \mu_{it} \quad (4)$$

We have used the panel ARDL technique to estimate the results for the period from 1991 to 2020. Table 2 shows data its measurement and sources.

Table 2: Data: Measurement and Sources

Variables	Measurement	Source
GG	Environmental adjusted multifactor productivity growth (in percentage)	OECD
GDP	Gross Domestic Product (% annual)	WDI
CO2	Carbon Dioxide Emissions (Metric Tons of CO_2)	WDI
EFTI	Environment Friendly Technological Innovation (% of all technologies)	OECD
REC	Renewable Energy Consumption (% of total final energy consumption)	WDI
ETAX	Environmental Related Tax (In USD)	OECD
HC	Human Capital (Based on Years of Schooling and Returns to Education)	PWT
FDI	Foreign Direct Investment, Net Inflows (% of GDP)	WDI
TO	Trade Openness (% of GDP)	WDI

4. Results and Discussions

Now we explain the results.

4.1. Descriptive Statistics and Correlation Analysis

Table 3 shows the results of descriptive statistics for key indicators of 38 OECD member countries using panel data from 1991 to 2020. The mean CO2 emissions are 8.23 with a considerable range from 0.96 to 30.44. The standard deviation is 4.42, indicating notable variability around the mean. The distribution is positively skewed (skewness = 1.25) and has high kurtosis (kurtosis = 5.42), implying a distribution skewed to the right with heavy tails. GDP statistics show substantial variability, ranging from -14.8 to 37.37, with a mean of 2.78. The distribution is positively skewed (skewness = 1.00) and highly leptokurtic (kurtosis = 15.06), indicating a highly skewed distribution with very heavy tails. Green Growth varies widely, ranging from -12.93 to 32.74, with a mean of 2.52. The distribution is positively skewed (skewness = 0.72) and leptokurtic (kurtosis = 11.54), suggesting a distribution skewed to the right with heavy tails. Environmental Friendly Technological Innovation (EFTI) statistics show a high mean (7031.59) and substantial variability, with a range from 10.08 to 86577.07. The distribution is highly positively skewed (skewness = 3.37) and leptokurtic (kurtosis = 13.41), indicating a skewed distribution with heavy tails. Renewable Energy Consumption (REC) varies from 0.44 to 78.49, with a mean of 18.33. The distribution is positively skewed (skewness = 1.35) and leptokurtic (kurtosis = 4.78), suggesting a distribution skewed to the right with moderately heavy tails. Environmental-related Taxes (ETAX) has a moderate mean (2.32) and low variability. The distribution is symmetric (skewness = 0.00) but leptokurtic (kurtosis = 3.91), indicating a distribution with heavy tails. Human Capital (HC) has a mean of 3.14 and ranges from 1.81 to 3.93. The distribution is negatively skewed (skewness = -0.78) and leptokurtic (kurtosis = 3.13), suggesting a distribution skewed to the left with moderately heavy tails. Foreign Direct Investment (FDI) varies widely, ranging from -57.53 to 108.42, with a mean of 4.30. The distribution is highly positively skewed (skewness = 3.96) and very leptokurtic (kurtosis = 35.94), indicating a distribution skewed to the right with very heavy tails. Trade openness vary widely, ranging from 15.81 to 380.10, with a mean of 86.07. The distribution is positively skewed (skewness = 2.10) and leptokurtic (kurtosis = 9.74), suggesting a distribution skewed to the right with heavy tails.

Table 3: Summary Statistics of Key Variables (1991-2020)

	CO_2	GDP	GG	EFTI	REC	ETAX	HC	FDI	TRADE
Mean	8.23	2.78	2.52	7031.59	18.33	2.32	3.14	4.30	86.07
Median	7.69	2.74	2.65	832.19	13.25	2.38	3.22	2.41	71.10
Maximum	30.44	37.37	32.74	86577.07	78.49	5.36	3.93	108.42	380.10
Minimum	0.96	-14.8	-12.9	10.08	0.44	-1.53	1.81	-57.53	15.81
Std. Dev.	4.42	3.86	3.77	17444.34	15.71	0.90	0.43	9.75	50.65
Skewness	1.25	1.00	0.72	3.37	1.35	0.00	-0.78	3.96	2.10
Kurtosis	5.42	15.06	11.54	13.41	4.78	3.91	3.13	35.94	9.74
JB	576	7097	3564	7309	498	40	117	54524	2995
Probability	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Obs.	1140	1140	1140	1140	1140	1140	1140	1140	1140

Table 4 presents a correlation matrix of key variables spanning the years 1991 to 2020. GDP has a very weak positive correlation (0.02) between CO2 emissions and GDP. This suggests a slight tendency for GDP and CO2 emissions to increase together, although the correlation is negligible. Green Growth and CO2 emissions have a positive correlation of 0.09. While this correlation is still relatively weak, it indicates a slight tendency for higher government spending to be associated with slightly higher CO2 emissions. EFTI has a moderate positive correlation (0.31) between CO2 emissions and environmental friendly technological innovation. This suggests that as innovation in environmentally friendly technology increases, CO2 emissions also tend to increase, possibly due to the overall increase in industrial activity associated with technological innovation.

Table 4: Correlation Matrix of Key Variables (1991-2020

Variables	CO_2	GDP	GG	EFTI	REC	ETAX	HC	FDI	TRADE
CO_2	1.00								
GDP	0.02	1.00							
GG	0.09	0.63	1.00						
EFTI	0.31	-0.11	-0.08	1.00					
REC	-0.37	0.00	-0.01	-0.27	1.00				
ETAX	0.05	-0.07	-0.10	-0.27	-0.04	1.00			
HC	0.10	-0.04	-0.03	-0.06	-0.08	0.04	1.00		
FDI	0.10	0.07	0.06	-0.11	-0.09	0.04	0.10	1.00	
TRADE	0.24	0.10	0.04	-0.32	-0.08	0.20	0.11	0.35	1.00

CO2 emissions and renewable energy consumption have a moderate negative correlation (-0.37). This indicates an inverse relationship, suggesting that as renewable energy consumption increases, CO2 emissions tend to decrease. There is a very weak positive correlation (0.05) between CO2 emissions and environmental taxes. This suggests a slight tendency for higher environmental taxes to be associated with slightly higher CO2 emissions, though the correlation is minimal. CO2 emissions and human capital have a weak positive correlation (0.10), indicating a slight tendency for higher human capital to be associated with slightly higher CO2 emissions. CO2 emissions and foreign direct investment have a weak positive correlation (0.10), suggesting a slight tendency for higher foreign direct investment to be associated with slightly higher CO2 emissions. CO2 emissions and trade volumes have a moderate positive correlation (0.24), indicating a moderate tendency for higher trade volumes to be associated with slightly higher CO2 emissions.

4.3. Unit Root Analysis

Table 5 shows that results of panel unit root tests at level. The table shows the mixed order of integration. The results exhibit that CO_2 EFTI, REC and HC are non-stationary while all other variables have no unit root.

Table 5: Results of Panel Unit Root Tests at Level

Variables	Intercept				Intercept & Trend				None			Conclusion
	LLC Test	IPS Test	ADF-Fisher Chi-Square	PP-Fisher Chi-Square	LLC Test	IPS Test	ADF-Fisher Chi-Square	PP-Fisher Chi-Square	LLC Test	ADF-Fisher Chi-Square	PP-Fisher Chi-Square	
CO2	6.36932 (1.0000)	8.00491 (1.0000)	43.8185 (0.9989)	46.3910 (0.9971)	-0.90658 (0.1823)	0.97122 (0.8343)	75.4371 (0.4967)	68.9121 (0.7052)	6.72755 (1.0000)	33.6978 (1.0000)	37.1113 (1.0000)	I (1)
GDP	-7.79650 (0.0000)	-12.0707 (0.0000)	295.960 (0.0000)	299.943 (0.0000)	-4.69676 (0.0000)	-11.3337 (0.0000)	260.390 (0.0000)	524.383 (0.0000)	-12.6821 (0.0000)	299.405 (0.0000)	295.287 (0.0000)	I (0)
GG	-9.77300 (0.0000)	-11.7803 (0.0000)	306.943 (0.0000)	332.551 (0.0000)	-13.1651 (0.0000)	-13.3413 (0.0000)	316.544 (0.0000)	531.528 (0.0000)	-9.45464 (0.0000)	237.303 (0.0000)	236.157 (0.0000)	I(0)
EFTI	-0.83561 (0.2017)	3.54235 (0.9998)	77.6779 (0.4250)	48.7470 (0.9937)	5.21391 (1.0000)	6.68207 (1.0000)	51.3599 (0.9865)	82.7970 (0.2778)	1.47870 (0.9304)	50.5151 (0.9893)	34.8900 (1.0000)	I(1)
REC	-3.45954 (0.0003)	-1.36910 (0.0855)	120.614 (0.0009)	128.226 (0.0002)	-7.67305 (0.0000)	-4.16818 (0.0000)	38.657 (0.0000)	248.032 (0.0000)	-4.57362 (0.0000)	129.782 (0.0001)	138.058 (0.0000)	I(1)
ETAX	-0.80786 (0.2096)	-0.56221 (0.2870)	102.715 (0.0223)	102.621 (0.0227)	-1.68810 (0.0457)	-2.51848 (0.0059)	116.203 (0.0021)	120.432 (0.0009)	-6.30767 (0.0000)	123.914 (0.0004)	118.622 (0.0013)	I(0)
HC	0.38525 (0.6500)	5.18050 (1.0000)	197.451 (0.0000)	248.193 (0.0000)	-2.49300 (0.0063)	-0.80124 (0.2115)	133.013 (0.0001)	80.1318 (0.3508)	41.6597 (1.0000)	2.90554 (1.0000)	0.28555 (1.0000)	I(1)
FDI	-11.6398 (0.0000)	-12.5212 (0.0000)	307.974 (0.0000)	295.769 (0.0000)	-11.1765 (0.0000)	-10.3766 (0.0000)	248.460 (0.0000)	235.491 (0.0000)	-5.92376 (0.0000)	173.443 (0.0000)	219.688 (0.0000)	I(0)
TRADE	-4.26873 (0.0000)	-0.17767 (0.4295)	80.8464 (0.3304)	100.747 (0.0303)	-4.93560 (0.0000)	-2.86504 (0.0021)	123.034 (0.0005)	95.6773 (0.0631)	4.79519 (1.0000)	16,6864 (1.0000)	14.6391 (1.0000)	I(0)

4.4. ARDL Analysis of Environmental Quality

Table 6 provides the results long run ARDL results of environmental quality based on Green and Non-Green Growth. The effect of green growth and non-green growth on CO_2 is positive and statistically significant. Environmental Kuznets Curve (EKC) examines the link between economic growth and environmental quality. In the context of EKC, Green GDP, and CO2 emissions have not shown the same pattern of these variables as it shows that initially as Green GDP grows, environmental degradation falls and when there is the decoupling of Green GDP growth, CO2 emissions decrease further (Yin et al., 2015; Su et al.,2020; Umar et al., 2020; Ling Guo et al., 2017; Sohag et al., 2019; Sandberg et al., 2019; Hao., et al., 2021). This is due to the fact that Green GDP accounts for environmental factors and promotes environmental sustainability. So far as conventional GDP growth (Non-Green GDP) leads to increased CO2 emissions initially and the after higher GDP growth, CO2 emissions again decrease which validates the EKC (Sherawat et al., 2015; Kocak, 2020; Zameer et al., 2020; Khan et al., 2021).

Environmentally friendly technological innovation (EFTI) has a negative and significant effect on environmental quality with green growth and non-green growth but the magnitude of the coefficient indicates that environmentally friendly technological innovation is high with non-green growth. Technology is a major component of the renewable energy sector. New methods for producing power might be developed over time, or manufacturing costs might decrease significantly. In other words, technology innovation can facilitate the growth of the renewable energy sector leading to a reduction in carbon emissions and also improving environmental quality. Manufacturing and production technology innovation is referred to as technological innovation. Technological innovation is specifically defined as the creation of new ideas, the creation and use of innovative patents and technologies, and the change of the current manufacturing method. It is believed that technological innovation holds the key to solving environmental issues and promoting sustainable development (Cheng et al, 2021). Our study has found that technical

innovation is crucial for fostering green growth by reducing harmful externalities, especially carbon intensity. According to Sohag et al. (2015), energy intensity reduces the benefits of technological advancements that support green growth (Hang and Tu, 2007). Newer technologies, referred to as "hybrid technologies", are argued to be more energy-efficient and to consume less energy, or fossil fuels, during production.

The coefficients of renewable energy consumption (REC) are negatively correlated with environmental quality in both models. Renewable energy consumption indicates that an increase in renewable energy consumption also results in a decrease in CO2 emissions. The biggest issues will be energy consumption and environmental deterioration because of the world's fast economic growth and dependency on energy sources. The burning of fossil fuels increases CO_2 emissions. Khan et al. (2021) state that producing goods for industry and agriculture requires energy, which leads to an increase in CO_2, nitrous oxide, and methane emissions. These concerns can be overcome by using renewable energy sources as an alternative to non-renewable energy sources. As a result of an increase in REC, environmental quality will be affected in the long time period Alharthi et al. (2021). Khan et al. (2021) concluded that clean energy sources would maintain the nation's economic progress. Creating and implementing sensible laws to restrain the practices of the energy and manufacturing sectors will contribute to the country's sustainable growth (Allard et al, 2018; Alharthi et al, 2021). According to Akram et al. (2019), energy efficiency can reduce CO2 emissions in the industrial, transportation, and construction sectors of China.

Table 6: Long Run ARDL Results of Environmental Quality Based on Green and Non-Green Growth

Dependent Variable: Co2 Selected model: ARDL (2, 1, 1, 1, 1, 1, 1, 1, 1) Green Growth			Dependent Variable: Co2 Selected model: ARDL (2, 1, 1, 1, 1, 1, 1, 1, 1) Non-Green Growth		
Variable	Coefficient	Prob.	Variable	Coefficient	Prob.
GG	-0.100030	0.0000	GDP	0.444933	0.0000
GG^2	-0.005492	0.0013	GDP^2	-0.025041	0.0000
EFTI	-0.000139	0.0000	EFTI	-0.000151	0.0000
REC	-0.214115	0.0000	REC	-0.169464	0.0000
ETAX	-0.016751	0.0644	ETAX	-0.717735	0.0000
HC	-0.531100	0.0968	HC	-1.064844	0.0004
FDI	0.029002	0.0399	FDI	0.085660	0.0000
TRADE	0.041485	0.0000	TRADE	0.023969	0.0000

The effect of environmental-related tax (ETAX) on CO_2 emissions is negative and significant in green growth and non-green growth equations. Environmental taxes and reformed rules can promote energy efficiency and sustainability by promoting subsidies for renewable products, cutting-edge technology, and research and development (Khurshid and Deng (2021). It has been demonstrated empirically that pollutant emissions and greenhouse gases adversely affect human health, economy, and environment. To address the persistent problems, it is essential to understand the role of energy and develop appropriate solutions. The role of environmental rules and levies in energy structure and energy economics has become increasingly significant in recent years. According to Shahzad et al., (2020), advanced economies, particularly those of the OECD and Europe are setting the standard for adopting and developing policies and taxes to mitigate climate change. Imposing taxes on pollution-related goods will improve the quality of the environment (Hao et al, 2021).

The coefficients of human capital (HC) have negative effects on CO_2 emissions in both green growth and non-green growth equations. By increasing human capital through education and investment, people may be more aware of the importance of employing environmentally friendly technologies. Through education and investment, we can increase the standard of human capital and make the general public more aware. The activities to reduce CO_2 emissions may be more effective if human capital is developed. Our study findings are in line with (Bano et al., 2018; Saleem and Shujah-ur-Rahman, 2019; Hao et al., 2021).

The relationship between foreign direct investment and carbon emissions is positive and significant in both models. The rising FDI causes environmental degradation. Due to weak environmental regulations, high-polluting companies can operate in these countries. A lack of effective environmental programs may result in the transfer of unclean technologies from outside the country. Our findings are consistent with the pollution haven hypothesis model. The studies by Tanveer et al. (2021), Zameer et al. (2020), and Li et al. (2021) also validate our results[4].

The coefficients of trade have a positive and significant impact on the quality of the environment.

Many economic theories account for the beneficial effect of trade openness on CO2 emissions; one well-known theory is the Pollution Haven Hypothesis. This theory suggests that the phenomena of "pollution havens" may cause countries with more open trade policies to have higher levels of CO2 emissions. Our findings are compatible with Tiwari et al. (2022) and Arif et al. (2020). Table 7 displays the short-run ARDL results of environmental quality based on green growth and non-green growth.

The signs of Error correction terms (ECT) are negative and significant in both models which shows the convergence towards equilibrium.

[4] According to (Chen et al. 2019, Khan et al. 2020; Tawiah et al, 2021; Rafindadi et al. 2018, Khan et al. 2020, Tawiah et al. 2021), foreign direct investment has a negative effect on the environment.

Table 7: Short-Run ARDL Results of Environmental Quality Based on Green Growth and Non-Green Growth

Dependent Variable: Co2

Selected models: ARDL (2, 1, 1, 1, 1, 1, 1, 1, 1)

Green Growth			Non-Green Growth		
Variable	Coefficient	Prob.	Variable	Coefficient	Prob.
ECT	-0.153075	0.0000	ECT	-0.095861	0.0020
$D(CO_2(-1))$	0.008136	0.8253	D(CO2(-1))	-0.094016	0.0894
D(GG)	-0.03838	0.0003	D(GDP)	0.013327	0.4052
$D(GG^2)$	-0.006656	0.0018	D(GDP(-1))	-0.000874	0.9445
D(EFTI)	0.000809	0.6297	$D(GDP^2)$	-0.001792	0.4555
D(REC)	-0.198826	0.0000	$D(GDP^2(-1))$	0.001555	0.5850
D(ETAX)	0.157299	0.2441	D(EFTI)	0.001872	0.4417
D(HC)	-4.271506	0.1153	D(EFTI(-1))	0.000860	0.6790
D(FDI)	0.002313	0.7711	D(REC)	-0.196769	0.0000
D(TRADE)	0.001688	0.7112	D(REC(-1))	-0.017849	0.5471
C	1.957915	0.0000	D(ETAX)	0.169901	0.2045
			D(ETAX(-1))	0.060505	0.7123
			D(HC)	-5.706581	0.0658
			D(HC(-1))	-2.272982	0.3963
			D(FDI)	-0.003051	0.7510
			D(FDI(-1))	0.008968	0.4681
			D(TRADE)	0.004381	0.4586s
			D(TRADE(-1))	-0.008046	0.1944
			C	1.102705	0.0057

5. Conclusions and Policy Recommendations

The study examined the green growth, environmental quality, and energy consumption nexus in OECD countries using panel data from 1991 to 2020. We have taken two models: i) Green Growth and ii) Non-Green Growth. The first model has explored the impact of green growth on environmental quality and the second model has probed the link between Non-Green Growth and Environmental Degradation. For this purpose, the ARDL technique has been used to estimate the results. Green Growth and Green Growth squared have a significant and negative relationship with environmental degradation. In the case of Non-Green Growth and Non-Green Growth squared variables, we have found a significant and inverted U-shaped relationship with environmental degradation which validates the EKC theory. Moreover, all other variables turn out with negative signs except FDI and Trade.
Following are policy recommendations to reduce or decarbonize the economies.

- The government may introduce a carbon tax or cap-and-trade system to internalize the external costs of carbon emissions, incentivizing businesses to reduce their CO2 emissions.
- Allocate resources towards developing renewable energy infrastructure such as solar, wind, and hydroelectric power plants.
- Policymakers may provide incentives, grants, and funding for research and development in environmentally friendly technologies such as carbon capture and storage, green transportation, and sustainable agriculture.
- The goernment should invest in education and training programs focused on environmental science, sustainability, and clean energy technologies. Moreover, there is need to implement and enforce stringent environmental regulations and standards to govern industrial processes, emissions, and waste management practices.
- The planners may offer incentives and tax breaks to attract foreign direct investment (FDI) in renewable energy projects, sustainable infrastructure, and green technologies.
- Develop and implement policies that prioritize sustainable development goals, ensuring that economic growth is decoupled from environmental degradation. Furthermore, there is a need to invest in research and development initiatives focused on improving environmental productivity, efficiency, and sustainability across various sectors.

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