

Authors' contribution /
Wkład autorów:
A. Study design /
Zaplanowanie badań
B. Data collection /
Zebranie danych
C. Statistical analysis /
Analiza statystyczna
D. Data interpretation /
Interpretacja danych /
E. Manuscript preparation /
Przygotowanie tekstu
F. Literature search /
Opracowanie
piśmiennictwa
G. Funds collection /
Pozyskanie funduszy

ORIGINAL ARTICLE
JEL code: O47, H23, Q54,
Q53, H41, Q42
Submitted:
June, 2025
Accepted:
June, 2025
Tables: 9
Figures: 0
References: 25

ORYGINALNY ARTYKUŁ
NAUKOWY
Klasyfikacja JEL: O47,
H23, Q54, Q53, H41, Q42
Zgłoszony:
czerwiec 2025
Zaakceptowany:
czerwiec 2025
Tabele: 8
Rysunki: 0
Literatura: 25

GREEN GROWTH NEXUS: ANALYSING ENVIRONMENTAL PERFORMANCE AND GDP TRENDS IN OECD ECONOMIES

ZIELONY WZROST GOSPODARCZY: ANALIZA WYNIKÓW W ZAKRESIE OCHRONY ŚRODOWISKA I TRENDÓW PKB W GOSPODARKACH KRAJÓW OECD

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Citation: Keerthana K, Pachiyappan, S., Joseph, A., Vellaiyan, S., Raj V, J., P. (2025). Green Growth Nexus: Analysing Environmental Performance and GDP Trends in OECD Economies / Zielony wzrost gospodarczy: analiza wyników w zakresie ochrony środowiska i trendów PKB w gospodarkach krajów OECD / *Economic and Regional Studies / Studia Ekonomiczne i Regionalne* 18(3), 256-269 <https://doi.org/10.2478/ers-2025-0021>

Abstract

Subject and Purpose of the Work: Over the past two decades, OECD countries such as Italy, Germany, France, and the United Kingdom have experienced consistent economic growth, averaging 2% annually in GDP. This upward trend has been driven by various factors, including government spending, investment rates, and favourable global conditions. Recently, environmental performance has emerged as a critical factor influencing economic development. This study aims to examine the relationship between environmental performance indicators and GDP growth in selected OECD countries, focusing on the growing emphasis on environmental sustainability.

Materials and Methods: The analysis uses panel data from the OECD and World Bank, spanning 25 years (2000–2024), for four OECD nations. The study employs a Panel Autoregressive Distributed Lag (ARDL) model, which allows for the estimation of both short-run and long-run dynamics. GDP growth is the dependent variable, while the independent variables include environmental tax revenue (TAX), greenhouse gas emissions (EMI), air quality (QUA), government expenditure on environmental protection (EXP), and the share of renewable energy in total energy supply (REN).

Results: The empirical findings indicate that TAX and EXP have minimal positive impact on GDP growth, suggesting potential inefficiencies in the allocation or effectiveness of environmental funds. In contrast, other indicators such as air quality and renewable energy share show a stronger link with economic growth.

Conclusion: The study highlights the growing significance of environmental performance in shaping economic outcomes. It contributes to the sustainable development literature by demonstrating that targeted environmental efforts can positively influence long-term economic growth.

Keywords: GDP Growth, Environmental tax revenues, Greenhouse gas emissions, Air quality, Government expenditure on Environmental protection, Renewable energy production

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Journal included in: AgEcon Search; AGRO; Arianta; Baidu Scholar; BazEkon; Cabell's Journalytics; CABI; CNKI Scholar; CNPIEC – cnpLINKer; Dimensions; DOAJ; EBSCO; ERIH PLUS; ExLibris; Google Scholar; Index Copernicus International; J-Gate; JournalTOCs; KESLI-NDL; MIAR; MyScienceWork; Naver Academic; Naviga (Softweco); Polish Ministry of Science and Higher Education; QOAM; ReadCube, Research Papers in Economics (RePEc); SCILIT; Scite; SCOPUS, Semantic Scholar; Sherpa/RoMEO; TDNet; Ulrich's PeriodicalsDirectory/ulrichsweb; WanFang Data; WorldCat (OCLC); X-MOL.

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Streszczenie

Przedmiot i cel pracy: W ciągu ostatnich dwóch dekad kraje OECD, takie jak Włochy, Niemcy, Francja i Wielka Brytania, odnotowały stały wzrost gospodarczy, wynoszący średnio 2% PKB rocznie. Ta tendencja wzrostowa była napędzana przez różne czynniki, w tym wydatki rządowe, stopy inwestycji i sprzyjające warunki globalne. W ostatnim czasie wyniki w zakresie ochrony środowiska stały się kluczowym czynnikiem wpływającym na rozwój gospodarczy. Niniejsze badanie ma na celu zbadanie związku między wskaźnikami wyników w zakresie ochrony środowiska a wzrostem PKB w wybranych krajach OECD, koncentrując się na rosnącym znaczeniu zrównoważonego rozwoju środowiska.

Materiały i metody: W analizie wykorzystano dane panelowe z OECD i Banku Światowego, obejmujące 25 lat (2000–2024) dla czterech krajów OECD. W badaniu zastosowano model panelowy autoregresyjny z rozłożonym opóźnieniem (ARDL), który pozwala na oszacowanie zarówno dynamiki krótkoterminowej, jak i długoterminowej. Wzrost PKB jest zmienną zależną, natomiast zmienne niezależne obejmują dochody z podatków środowiskowych (TAX), emisje gazów cieplarnianych (EMI), jakość powietrza (QUA), wydatki rządowe na ochronę środowiska (EXP) oraz udział energii odnawialnej w całkowitym zużyciu energii (REN).

Wyniki: Wyniki badań empirycznych wskazują, że podatki i wydatki mają minimalny pozytywny wpływ na wzrost PKB, co sugeruje potencjalną nieefektywność alokacji lub skuteczności funduszy środowiskowych. Natomiast inne wskaźniki, takie jak jakość powietrza i udział energii odnawialnej, wykazują silniejszy związek ze wzrostem gospodarczym.

Wnioski: Badanie podkreśla rosnące znaczenie wyników w zakresie ochrony środowiska dla kształtowania wyników gospodarczych. Stanowi ono wkład w literaturę dotyczącą zrównoważonego rozwoju, wykazując, że ukierunkowane działania na rzecz ochrony środowiska mogą pozytywnie wpływać na długoterminowy wzrost gospodarczy.

Słowa kluczowe: Wzrost PKB, dochody z podatków środowiskowych, emisje gazów cieplarnianych, jakość powietrza, wydatki rządowe na ochronę środowiska, produkcja energii odnawialnej

Introduction

While countries are looking forward to guaranteeing environmental sustainability and economic growth concurrently, the connection between economic growth and environmental performance is even more vital. Given the climate change, natural resource scarcity, and pollution as the most significant problems on the international agenda, economic growth versus nature conservation cannot be overstressed. Regulations, innovation, management of resources, and more all influence economic growth, which is generally represented by GDP change. Environmental policy has been required to ensure sustainable economic development. Long-term economic effects of environmental deterioration, including declining farm production, health spending, and flight into industry, would more than compensate for all short-term dollar profits in the absence of control of the environment and concerted investment. Research has established that countries emphasizing the imposition of environmental taxation and raising government spending on the environment are likely to realize improvement in economic performance (Hassan et al., 2020).

In addition, two environmental performance indicators closest to economic prosperity are greenhouse gases and air quality. The release of greenhouse gases results in climate change, whose effects on the economy can be extreme as they cause infrastructure destruction, disrupting supply chains, and destroying biodiversity required by various industries. Inadequate air quality can pose long-term public health issues that lower the productivity of employees and raise healthcare expenditure. Strong environmental regulations and cleaner air are associated with better public health and more robust economies, according to Neagu et al. (2017). The reason is that the environmental aspects must be accounted for whenever a country is making economic decisions. The use of renewable sources of energy is also another central consideration that has both an environmental effect as well as an economic effect. Besides relieving environmental problems, renewable energy utilization in a country's diversification of energy fosters economic development via the creation of new employment opportunities (Lee, Olasehinde-Williams, 2024). Investment in renewable energy technology would likely enhance energy security and minimize dependence on fossil fuels and consequently make economies shock-resilient.

Policy-makers have to understand such inter-linkages since they want to implement policies to deliver sustainable development and growth in economies. The countries included in the study were OECD member nations. This selection was primarily based on the comparability of economic structures and

the availability of reliable data. The use of OECD countries ensures a level of uniformity in terms of data quality and economic development, making cross-country comparisons more robust. Since their environmental policies and economies are well developed, OECD countries in general offer an appropriate context for examining the relation between environmental performance indicators and growth in GDP. This research will examine the influence on GDP growth of a set of OECD countries by various measures of environmental performance, such as air pollution, greenhouse gas, environmental revenue in the form of taxation, government expenditure on the environment, and proportion of renewable energy as a percentage of total energy supply.

Environmental Protection and Economic Growth

The following literature gives insights in to existing studies examining the economic growth and environmental protection nexus from different countries. The relationship between environmental protection and economic growth has been studied in various contexts and approaches to a great extent, and there is much to be understood about the relationship between growth, regulation, and taxation. (Zelenović et al., 2024) examine the effect of tax revenues from the environment on Nordic economies' economic growth and conclude that tax revenues from energy and transport considerably increase GDP per capita, whereas tax revenues from pollution, although positive, are negligible. This provides insight to the assertion that an increase in environmental and particularly pollution taxation could contribute towards sustainable growth and, with future potential, implications of a healthy nature. Temporary downturns within economies could potentially be caused by moves towards green protection, however, according to (Peng et al., 2020) these measures would provide long-term economic gains for green infrastructure along with interregional cooperation. Thomakos and Alexopoulos (2022) reference Economic Growth and Environmental Performance Index (EPI) as a direct correlation of EPI and GDP, particularly for developed economies. They theorize that there will be increased economic growth accompanied by decreased environmental performance in advanced economies but that such a trend does not hold when applied to middle-income economies, thus necessitating the use of reverse causality. (Thomakos, Alexopoulos, 2016) tested the link between GDP per capita and Environmental Performance Index among 166 nations in 2016 and found it to be positively related whereby, a rise by 1% in GDP elevates EPI by 23.47 points. (Lee et al., 2022). examined the link between environmental performance and economic complexity of the OECD nations utilizing a reformulated STIRPAT model. The findings prove economic complexity to have a significant positive effect on environmental performance, which is confirmed using Driscoll-Kraay fixed effects and GMM. (Singh, 2020) also tested whether economic development (per capita GDP) and environmental performance are related to each other among 96 countries for 1990 and 2005, and 94 countries for 2014. Based on factor analysis to build the EPI from various indicators, the paper shows that economic development is related to better environmental performances. Almarafi et al. (2023) research explores environmental performance index, financial growth, and economic growth interlinkages in developed nations. 2018-2022 literature reviews affirm that there is an association between the environment and economic growth as green policy and sustainable finance drive development within emerging nations (Almarafi et al., 2023). (Sheikhzeinoddin et al., 2021) studies the interrelation among environmental performance, economic development, and industrialization in the MENA region. It applies the EKC hypothesis and panel ARDL method and finds that growth factors have negative impacts on performance and efficient policies have positive impacts.

Air Quality, Greenhouse gas emissions and Economic Growth

(Galeotti, 2003), in his book on the Environmental Kuznets Curve (EKC), overviews the manner in which pollution increases with development before, then, decreasing once a level of income has been attained, in indicating a requirement for additional empirical evidence upon which policy should be directed towards sustainable development. Central European research validates that green protection

expenditures by the public have a positive impact on GDP, affirming once more that environmental protection can yield desirable macroeconomic effects (Krajewski, 2016).

Shafik and Bandyopadhyay (1992) discuss the relationship between environmental quality and economic growth in 66 nations based on eight indicators like deforestation and greenhouse gas emissions. They conclude that environmental quality is influenced by income in various ways; all except safe water and sanitation decline with increased incomes. The article again emphasizes that excessive investment can strain natural resources, but some indicators improve with increased incomes. (Shafik, Bandyopadhyay, 1992).

Government expenditure and policies on environmental protection

(Zeng, Eastin, 2012) also prove that foreign direct investment and international trade in China are able to promote environmental protection by the imposition of stricter ecological standards from export markets, inducing self-regulation on the part of firms. (Yang, et al, 2024), Under night light and environmental pressure data, the indicators point to dramatic environmental performance improvements in China after 2014 but reveal geographical disparities that need to be addressed by localized policy intervention.

The research paper of A. Arjomandi et.al (2022) analyses the correspondence among environmental policy strictness, expenditures, and green GDP as well as the productivity growth in the OECD economies. Referring to the Pooled Mean Group Autoregressive Distributed Lag, short-and long-run effects are estimated by authors where they discover government environmental expenditure overwhelmingly increasing national output in the short run. (Arjomandi et al., 2022). (Marsiliani, Rengström, 2000) researched the interrelationship between environmental policy, income inequality, and economic growth and emphasized the role of measures for environmental policy as instruments both for regulation of the pollution and distribution effect on incomes. (List, Kuncze, 2000) in the US example states that environmental regulations can have adverse effects on employment creation, especially in polluting sectors, although the effects differ by sectors. (Rees, 2003) criticizes the extensive economic model and suggests minimizing human footprint on nature to reverse environmental disasters like global warming and extinction of species. Hence, the studies indicate the significance of environmentally balanced policy to economic stability and sustainability via taxation, controls, and inter-border cooperation.

Relationship between Environmental tax revenues and GDP growth

Through panel data analysis with static models such as Pooled OLS and Fixed Effects, Nino Stameski et al. (2024) established that the taxes greatly contribute to sustainable business and economic growth through financing renewable sources of energy and infrastructure in Nordic Countries between 2013 and 2022. The authors advise future studies regarding environmental tax policy in Eastern Europe and suggest adding more detailed environmental indicators for subsequent research. (Stameski et al., 2024) Hassan et al. (2020) employed 31 OECD countries' evidence (1994-2013). It concludes that environmental taxes are harmful to economic growth in that the initial GDP per capita reduces the effect and examines the effect of mechanisms of redistribution of revenues.

Renewable Energy Supply and GDP Growth

In developing countries, Sepehrdoust et al. (2017) indicate the impact of renewable energy, population increase, and internet use in curbing the emission of CO₂ taking into consideration the encouraging relationship between emissions and the industrial sector, making sustainable industrial policy imperative. These policies, with the aim of developing the economy by conserving the environment, are energy-promoting policies, reduction of emissions, and utilizing renewable energy sources. Mahnaz

Mamghaderi et al. (2023) use ecological footprint metrics and Data Envelopment Analysis (DEA) to assess the environmental performance of 27 OECD countries between 2000 and 2017. The desired output is GDP while the undesired outputs are ecological footprints. The most efficient of all the countries was the UK and the least efficient was Lithuania. The authors suggest that the study be rewritten based on new data, such as non-OECD nations, and concentrating on certain environmental policies. (Mamghaderi et al., 2023).

Based on the thorough literature review given, current research on environmental performance and economic growth focuses on a single environmental indicator, e.g., green-house gas emissions or a particular pollutant such as PM2.5 that does not allow for an understanding of their combined effect on GDP growth. Apart from this, most studies have centered on emerging economies, especially Middle East, South Africa, Nordic Nations and so on without for the dynamics in developed countries where regulatory regimes and economic structures might influence outcomes. Such exclusion rests upon a necessity to conduct analytical in-depth on the basis of numerous environmental performance indicators – i.e., revenues from environmental taxes, government spending on environmental protection, and proportion of renewable energy within the overall energy supply – when such dynamics are taken into account within the developed economies. This research intends to provide a broader perspective on how different environmental indicators influence GDP growth in the chosen OECD nations by filling such gaps (Yang et al., 2022).

Objectives

1. To analyse the short run and long run relationship between environmental performance factors and GDP growth in specific OECD Countries.
2. To understand the effectiveness of government interventions such as environmental taxes and green energy investments for economic expansion.
3. To benefit policymakers in implementing effective policies for the protection of the environment.

Hypotheses

H1 – There is a positive relationship between environmental tax revenues and GDP growth in selected OECD countries.

H2 – There is a negative relationship between higher greenhouse gas emissions and GDP growth in OECD countries.

H3 – There is a positive relationship between air quality (PM 2.5 levels) and GDP growth in OECD nations.

H4 – There is a positive relationship between government spending on environmental protection and GDP growth in selected OECD countries.

H5 – There is a positive relationship between a higher share of renewable energy in total energy supply and GDP growth in OECD countries.

Methodology of the study

The study is descriptive and analytical in nature. To accomplish the objective, the study used panel data from 2000 to 2024 of OECD countries. The data is collected from the OECD database and the World Bank. Table 1 depicts the variable chosen for the study, definition, unit of measurement, frequency, reference period and sources.

Table 1. Variable Definition and Sources

Variable	Variable Definition	Unit of Measurement	Reference Period	Source
Endogenous Variable				
GDP Growth (GDP)	Yearly percentage change in real GDP, showing economic growth or decline.	Percentage	2000 -2024	World Bank Database
Exogenous Variables				
Environmental Tax Revenue(TAX)	Government income from taxes targeting environmental impacts, measured annually.	US\$ (in millions)	2000 -2024	OECD Database
Greenhouse Gas Emissions (EMI)	Annual total emissions of gases contributing to global warming, measured in CO ₂ equivalents.	Million metric tons of CO ₂ equivalent	2000 -2024	OECD Database
Government Expenditure on Environmental protection (EXP)	Annual government spending on activities aimed at protecting the environment.	US\$ (in millions)	2000 -2024	OECD Database
Renewable Energy Supply (REN)	Yearly energy generated from renewable resources such as solar, wind, and biomass.	Percentage	2000 -2024	World Bank Database
Air Quality (QUA)	Annual average concentration of fine particulate matter (PM _{2.5}) in the air, measured in micrograms per cubic meter (µg/m ³).	Presence of PM 2.5 level	2000 -2024	OECD Database

Source: Author's calculation.

GDP growth rate is the representation of the change in the annual percentage in real GDP and is considered as an endogenous variable. The exogenous variables are Environmental Tax Revenue, Greenhouse Gas Emissions, Government Expenditure on Environmental Protection, Renewable Energy Supply and Air Quality. Descriptive statistics is used to describe the basic information about the variables used in the study and to highlight the relationship between the variables. The relationship among variables is studied using correlation analysis. Finally, the Autoregressive Distributed Lag Model (ARDL) model is used to check long run as well as short run impact.

Before using any econometric model, the order of integration is crucial for having internal inconsistency among the chosen variables. Table 2 shows the results of the Unit root test for the level and first differences via trend and intercept. Since panel data is used, the study has employed Im-Pesaran-Shin (IPS) unit root test. The results of the unit root test display that except TAX which is stationarity at level $I(0)$, GDP, EMI, EXP, QUA and REN are stationarity at first difference $I(1)$. However no variables are integrated after the second difference $I(2)$. Further performing ARDL bound testing, initially proposed by Pesaran and Shin (1998) and after that further development extended by Pesaran et al. (2001) is done to capture the short run and the long run cointegration among the variables.

Table 2. Summary of Unit Root Test Results

Variables	Trend and Intercept		Order of Integration
	Level	First Difference	
GDP	1.838(0.9760)	-1.582**(0.0568)	$I(1)$
EMI	3.27(0.995)	-4.216*(0.0000)	$I(1)$
EXP	3.798(0.999)	-3.221*(0.0006)	$I(1)$
QUA	3.406(0.9997)	-10.687*(0.0000)	$I(1)$
REN	3.035(0.9988)	-3.793*(0.0001)	$I(1)$
TAX	-1.521*** (0.064)	-4.0781*(0.0000)	$I(0)$

Note: *, **, *** significance at 1, 5, and 10 per cent level, () values indicate p values.

Source: Author's calculation.

Descriptive statistics is the initial test which is conducted during research and describes and summarizes the data in an organised manner. An overview of the six variables – GDP, TAX, EMI, EXP, REN, QUA is provided by the descriptive statistics which is presented in Table 3. A total of 100 observations of each variable have been considered for the study. With GDP reflecting the growth rate of the economy, TAX indicating the Governmental tax revenues, EXP depicting the Annual government spending on environmental protection activities, REN showing the percentage of renewable energy supply and EMI and QUA indicating the Greenhouse gas emissions and Air quality respectively, the mean value shows the average value of each variable throughout the research period. The degree of dispersion of the data with respect to the mean is indicated by the standard deviation.

Table 3. Summary of Descriptive Statistics

Variables	GDP	TAX	EMI	EXP	REN	QUA
Observations	100	100	100	100	100	100
Mean	2.33	62451.81	604.99	18068.41	6.066	14.09
S.D	0.59	12534.37	195.80	5014.20	3.56	4.037
Minimum	1.15	30232.96	384.97	8341.1	0.72	7.99
Maximum	4.5	86746	1053.14	33426.64	13.6	25.46

Source: Author's calculation.

The table 3 shows that among the variables the GDP growth (GDP) is relatively constant and Environmental Tax revenue (TAX) and Government Expenditure on Environmental Protection (EXP) is significantly dispersed. The largest and smallest observation called the maximum and minimum values respectively, shows the range of observations. The variables record a minimum value of 0.72% and a maximum value of USD 86,746(in millions)

Table 4. Correlation Matrix

	GDP	TAX	EMI	EXP	REN	QUA
GDP	1	-	-	-	-	-
TAX	0.671	1	-	-	-	-
EMI	0.326	0.117	1	-	-	-
EXP	0.574	0.561	-0.318	1	-	-
REN	0.335	0.420	-0.319	0.350	1	-
QUA	-0.448	-0.467	0.178	-0.797	-0.222	1

Source: Author's calculation.

Table 4 shows the correlation matrix between environmental performance measures and explanatory variables and their correlations with GDP. There is a very high positive correlation (0.671) between GDP and tax revenues that supports the thesis that tax revenue is a proxy for economic activity and hence highly correlated with economic growth. Furthermore, EXP (0.574), REN (0.335), and EMI (0.326) are also weakly positively correlated with GDP. GDP is, however, weakly negatively correlated with QUA (-0.448) which suggests that the economic growth process may be at the expense of environmental quality. A number of other variables are also significantly related: EXP and QUA are strongly negatively correlated (-0.797) and TAX is positively correlated with EXP (0.561) and REN (0.420). These findings indicate the correlation between variables of economic growth, environmental policy, and sustainability in the given sample.

Autoregressive Distributed Lag Model (ARDL)-Mean Group

The Panel Autoregressive Distributed Lag (ARDL) model has been chosen as the primary econometric tool for the research. The ARDL Mean Group (MG-ARDL) is a specific approach that can help with estimating panel data. Unlike other tools, the ARDL model can handle variables integrated at different orders, whether stationary or non-stationary, making it highly flexible (Pesaran et al., 2001). It is also efficient with limited sample sizes and has a general framework to make estimates of both short term and long term impact. Additionally, the error correction mechanism of the model also permits a consistent estimation of the adjustment towards equilibrium, eliminating the drawbacks of the standard approaches (Nkoro, Uko, 2016).

The study uses the panel data to estimate government expenditures on environmental protection, environmental tax revenues, greenhouse gas emissions, air quality, and the share of renewable energy in the total supply of energy on GDP growth of such selected OECD nations as Germany, France, Italy, and the UK.

$$GDP_{it} = \alpha_0 + \beta_1 EMI_{it} + \beta_2 EXP_{it} + \beta_3 QUA_{it} + \beta_4 REN_{it} + \beta_5 TAX_{it} + \epsilon_{it}$$

The main reason to use panel data is that it measures the impact in a group and not in individual units, which means that very little information is lost by taking the panel perspective. The current model of Panel ARDL is particularly suited for datasets where variables are integrated of mixed order, i.e., I(0) and I(1), making it flexible and reliable in empirical research involving time series and cross-sectional dimensions. Moreover, the model is an appropriate and robust methodological choice for this study due to its ability to handle the characteristics of macroeconomic panel data.

Furthermore, the model accommodates heterogeneity in short-run dynamics across cross-sectional units, such as different OECD countries, while still allowing for a common long-run relationship. This feature makes the findings more reflective of the diverse economic environments within the sample. Additionally, it performs well with panel datasets that have a moderate time dimension, which aligns with the structure of our data. Moreover, panel data reduces the noise coming from the individual time series; therefore, heteroscedasticity is not an issue in panel data analysis. In addition, panel data work best when the availability of the data is the problem, especially in developing nations where short-term variables are understood. Panel estimation methods address heterogeneity by introducing subject-specific variables along with dynamic variations for the repeated cross-sectional observations. This paper is strictly based on heterogeneous panel data modeling, or what is also called panel-ARDL. The Autoregressive Distributed Lag (ARDL) method is a strong and well-established econometric method that can determine the short-run as well as long-run relationships in the relationships in question.

Table 5. Impact of Environmental Tax Revenue (TAX) on Gross Domestic Product (GDP)

D.GDP	Coef	Std. Err	z	P> Z
LR				
TAX	0.120	0.747	0.160	0.872
SR				
ECT	-0.479	0.300	-1.59	0.111
TAX (D1)	-0.203	0.230	-0.88	0.379
_cons	-3.735	5.57	-0.67	0.503

Source: Author's calculation.

Table 5 shows the outcome of an Autoregressive Distributed Lag (ARDL) pooled mean group regression test for the effect of tax (TAX) on GDP growth (D.GDP) in some OECD countries. The TAX coefficient is positive (0.120), albeit with a huge p-value (0.872), and hence this effect is not statistically significant. Short term-wise, Error Correction Term (ECT) is negative (-0.479) and bordering on significance level

($p = 0.111$), implying a direction to revert towards long-run equilibrium upon shocks. Coefficient for TAX (D1) short-run is negative too (-0.203) but non-significant ($p = 0.379$), indicative of no statistical impact on the growth in GDP due to shocks from tax in the short run. The constant is negative (-3.735) but not statistically significant ($p = 0.503$). The findings indicate the fact that TAX has no statistically significant effect on GDP both in the short run as well as the long run on the sample provided. Thus H1 is rejected.

Table 6. Impact of Greenhouse Gas Emissions (EMI) on Gross Domestic Product (GDP)

D.GDP	Coef	Std. Err	z	P> Z
LR				
EMI	-2.007***	0.730	-2.75	0.006
SR				
ECT	-0.479	0.300	-1.59	0.111
EMI (D1)	1.142**	0.556	2.05	0.040
_cons	-3.735	5.57	-0.67	0.503

Note: *, **, *** significance at 1, 5 & 10 percent significantly

Source: Author's calculation.

Table 6 gives the outcome of a pooled mean group regression test to examine the effect of environmental management programs (EMI) on GDP growth (D.GDP) in selected OECD countries. The long-run coefficient for EMI is -2.007 and statistically significant at 1% ($p = 0.006$), which reveals that an increase in EMI is linked with a significant decrease in GDP growth in the long term. In the short term, the Error Correction Term (ECT) is negative (-0.479) with a p-value of 0.111, indicating that GDP converges to its long-run level but not significantly. The short-run coefficient of EMI (D1) is positive (1.142) and significant at the 5% level ($p = 0.040$), indicating a positive short-run effect of EMI on GDP growth. The constant term is negative (-3.735) but not significant ($p = 0.503$). Overall, one sees that despite possible positive short-run implications for GDP growth in EMI, the latter is shown to have negative implications for economic growth over the long term, if measures of environmental performance are considered in the case of chosen OECD countries. Hence H2 is accepted.

Table 7. Impact of Government Expenditure on Environmental Protection (EXP) on Gross Domestic Product GDP

D.GDP	Coef	Std. Err	z	P> Z
LR				
EXP	-0.148	0.621	-0.24	0.811
SR				
ECT	-0.479	0.300	-1.59	0.111
EXP (D1)	0.121	0.114	1.06	0.290
_cons	-3.735	5.57	-0.67	0.503

Source: Author's calculation.

Table 7 displays the output of pooled mean group regression estimation that tests the effect of exports (EXP) on GDP growth (D.GDP) in the chosen OECD nations. The long-run coefficient of EXP is negative (-0.148) and not statistically significant ($p = 0.811$), which means that fluctuations in exports do not have any appreciable effect on GDP growth in the long term. The ECT for the short run is -0.479 and is significant at 0.111, which implies that GDP tends to revert back to its long-run equilibrium after deviations but is not statistically significant. The short-run EXP coefficient (D1) is 0.121 but not statistically significant ($p = 0.290$), which implies that exports have no considerable effect on GDP growth in the short run. The intercept or constant term is negative (-3.735) but not significant ($p = 0.503$). Thus H4 is rejected.

Table 8. Impact of Renewable Energy Supply (REN) on Gross Domestic Product (GDP)

D.GDP	Coef	Std. Err	z	P> Z
LR				
REN	-0.267	0.318	-0.84	0.400
SR				
ECT	-0.479	0.300	-1.59	0.111
REN (D1)	0.448***	0.172	2.60	0.009
_cons	-3.735	5.57	-0.67	0.503

Note: *, **, *** significance at 1, 5 & 10 percent significantly

Source: Author's calculation.

Table 8 presents the outcome of a pooled mean group regression that tests the effect of renewable energy (REN) on GDP growth (D.GDP) in the sample OECD nations. The long-run REN coefficient is non-significant and negative (-0.267, $p = 0.400$) and thus indicates that renewable energy has no significant influence on the long-run growth of GDP. The ECT in the short-run is negative (-0.479) with a p -value of 0.111 and indicates that GDP does tend to return to its long-run equilibrium after deviations, albeit the latter is not statistically significant. The short-run REN coefficient is significant at 1% level (0.448, $p = 0.009$), as it means that renewable energy plays significantly in terms of contributing to the growth of GDP in the short run. The intercept term is also negative (-3.735) but not statistically significant ($p = 0.503$). This indicates that although renewable energy has a strong positive effect on GDP growth in the short run, it does not have much effect on long-run economic growth in the case of environmental performance determinants of the chosen OECD nations. Hence H5 is accepted.

Table 9. Impact of Air Quality (QUA) on Gross Domestic Product (GDP)

D.GDP	Coef	Std. Err	z	P> Z
LR				
QUA	0.485	0.556	0.87	0.383
SR				
ECT	-0.479	0.300	-1.59	0.111
QUA (D1)	0.183	0.231	0.79	0.430
_cons	-3.735	5.57	-0.67	0.503

Source: Author's calculation.

Table 9 reports the findings of a pooled mean group regression test that examined the effect of determinants of quality of environmental performance (QUA) on GDP growth (D.GDP) in some OECD countries. The long-run coefficient for QUA is significant and positive (0.485) but insignificant ($p = 0.383$), indicating that variations in the quality of environmental performance do not affect GDP growth in the long run. The short-run Error Correction Term (ECT) is also negative (-0.479) with a p -value of 0.111, showing that GDP tends to revert back to its long-run equilibrium in case of deviations, but the result is not statistically significant. The short-run QUA coefficient (D1) is also positive (0.183) but not statistically significant ($p = 0.430$), indicating that improved environmental quality does not affect GDP growth in the short run. The intercept is always negative but not significant (-3.735, $p = 0.503$). Therefore, H3 is rejected.

Results and Discussion

The results indicate the relationship of environmental performance indicators and GDP growth for the case of chosen OECD countries. There is a positive short-term relationship between renewable

energy (REN) and GDP growth ($p < 0.01$), which proves the economic advantages of utilizing renewable energy sources. Investments in renewable energy infrastructure would generate employment, enhance the security of the energy supply, and encourage innovativeness towards short-run economic growth. This conclusion is consistent with a study by (Lee and Olasehinde-Williams, 2022), whereby it is shown how renewable energy has the ability both to alleviate environmental issues and to stimulate economic growth. Despite this, the observation that there is no substantial long-term impact ($p > 0.05$) indicates that such a preliminary benefit may be wiped out once the industry stabilizes and matures. Policymakers need to keep this temporal factor in consideration while promoting renewable energy projects such that other policies encourage long-run growth.

Greenhouse gas emissions (EMI) depict a bilateral relationship with GDP growth. There is a significant negative long-run relationship ($p < 0.01$) that supports the fact that high emissions can be detrimental to the economy, resulting in productivity losses due to health issues and environmental degradation. This result is in line with (Neagu et al., 2017), who emphasized the significance of environmental quality for economic stability. Contrary to this, the short-run positive effect of emissions ($p < 0.05$) suggests that as industrial and energy-intensive operations increase the GDP of a nation increases along with the increase in emissions. This relationship represents the compromise between economic short-run gains and long-run sustainability issues, indicating a need for policies to ensure economic and environmental objectives in harmony.

Environmental tax revenue (TAX) is subjected to analysis and proven not to have any statistically significant short- and long-term effect on GDP growth ($p > 0.05$). Contrary to research such as that conducted by Stameski et al. (2024), in which it has been established that properly designed environmental tax systems would promote environmentally responsible behavior and enhance economic growth. The results indicate that, in the chosen OECD economies, environmental tax effectiveness can be constrained due to the lack of strategic allocation of the revenue generated. Likewise, government expenditure on environmental protection (EXP) does not show any statistical significance with GDP growth since it could be due to inefficiencies of their allocation and use. (Arjomandi et al. 2022) had observed that although environmental expenditures can bring positive economic impacts in the short run, they are highly reliant on the quality of resource management and application of resources to worthwhile projects, such as pollution control equipment or renewable energy infrastructure.

Findings in air quality (QUA) are not significantly remarkable. Contrary to other studies, which associate good air quality and economic development in a positive light, there is no significant impact of air quality on the advancement of the chosen nations' GDP growth ($p > 0.05$). (Neagu et al., 2017) discussed how better air quality tends to enhance productivity for workers as well as reduce healthcare costs, thus indirectly enhancing performance in the economy. However, the failure of this study to show substantial results can be attributed to variability in baseline air quality levels or to other factors dominating the economic advantages of cleaner air.

Overall, the findings are significant regarding the linkage of environmental performance measures and GDP growth. The identified short-run beneficial impacts of using renewable energy and emissions suggest potential immediate economic benefit, but these may be accompanied by losses of long-run sustainability. The long-term negative effect of emissions calls for the immediate change towards low-carbon economies. The marginal influence of environmental tax revenues and expenditure by governments to the environment reiterates the necessity of redesigning and initiating these policies. These findings supplement more general economic frameworks, recognizing the two-sided nature of environmental policy in order to help mitigate issues of sustainability challenges and making the economy more resilient (Hassan et al., 2020).

Implications

The outcome of this study supports the strong and positive relationship between renewable energy consumption and GDP growth for the selected OECD countries as a measure of the resilience and

flexibility of these economies towards green practices. The study shows that the nations are successfully utilizing the investment in renewable energy to stimulate economic growth, stability, and innovation. This adaptation strategy is centered on the possibility of environmental policy stimulating economic growth despite the threat from climate change and sustainability.

The research presents high correlations between GDP growth and environmental performance indices in a number of OECD nations, which can be utilized by policymakers as well as researchers. The clean energy investment GDP growth positive short-run relationship relates the economic benefits from clean energy investment. Government must encourage the investment in renewable energy infrastructure to generate employment and enhance energy security (Lehr et al., 2008). However, the absence of clear long-term effects translates into initial economic gains being guaranteed to vanish when the industry gets mature. The policymakers will be tasked with achieving a balance between sustainable growth policy, for example, more innovation and energy efficiency spending. Though the short-run economic benefits arise from the industrial emissions, their long-run environmental and health damages are difficult to overcome.

The findings on the government spending and environmental tax yields indicate potential inefficiencies in what is currently existing. The inability to demonstrate considerable impacts suggests raising environmental taxes or spending alone would not be effective in stimulating the economy. Such measures need to be well developed and well enacted by policymakers so that they reach desired ends. Second, the study discovered that air quality improvements do not always translate into measurable economic benefit in the short run, as had been argued by earlier studies (Dinda et al., 2000). This would mean further research on the complicated relationship between air quality and economic performance must be conducted and indicates that policy-makers are preoccupied with more theoretical socio-economic matters when considering air quality measures. In summary, the research elicits the importance of environmental performance measures towards economic growth. Policymakers need to employ a comprehensive strategy with economic and environmental goals synchronized, in such a manner that it facilitates OECD nations to realize short-term gains as well as long-term sustainability (Jacob et al., 2008).

Conclusion

This research offers valuable information on the connection between environmental performance indicators and GDP growth in the chosen OECD nations. In the research, it is argued that investment in renewable energy is not only lucrative in the short run but policymakers should never ever ignore the long-term considerations which may affect sustainability. In addition, since the emissions of greenhouse gases have twofold consequences, policies must be formulated in a way that they enhance economic growth without damaging the environment. The fact that environmental tax revenues and government expenditure on the environment are less effective limits the effectiveness of such policies, making them necessary to be well planned and implemented for them to produce positive economic outcomes. Collectively, the research emphasises the necessity for an overarching strategy to merge environmental and economic policy in pursuing sustainable development so as to allow nations to achieve the balance between economic growth and environmental sustainability amidst ongoing global change.

Limitations and Scope for Further Research

Despite the outcomes indicated on the premise of how different measures of environmental performance can affect GDP growth, this research does have some limitations to its credit. To begin with, the study is carried out using a sample of OECD nations – Italy, Germany, France, and the United Kingdom – thus its results might not be applicable to other nations that have a varying economic status or environmental protection regulations. Second, the estimates are based on secondary OECD and World Bank data subject to cross-country reporting error or volatility. Third, even if it is assumed that the Panel ARDL model is effective in distinguishing both short- and long-run dynamics, it would not be supposed

to distinguish all possible confounding determinants of GDP growth, such as technology, trade, or socio-political stability.

Thus, for future research, the study still holds much potential in the following fields: It would be helpful to extend the analysis to a wider number of nations, especially non-OECD nations, in order to enhance the understanding of how environmental performance variables impact GDP growth across different economic contexts. In addition, as a qualitative complement to quantitative evidence, qualitative research can be used to collect policy makers' perceptions regarding the green taxes and regulation effectiveness. Impacts experimentation on impacts of some environmental policies, like carbon tax or renewable energy subsidies, can be of further value. Lastly, long-term experiments on the effects of environmental programs could reveal cause-and-effect and prove long-term sustainability of such policies to sound economic growth.

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