GREEN ECONOMICS
Vol.2, No.1, 2024, pp.18-30

CARBON EMISSIONS AND ECONOMIC GROWTH: AN EMPIRICAL ANALYSIS FROM OECD COUNTRIES

Elza Qorraj – Haxhiu, Shenaj Haxhimustafa*

Faculty of Business and Economics, South East European University, Tetovo, North Macedonia

Abstract. In the face of escalating environmental challenges, this study assumes critical significance by exploring the interplay between carbon dioxide emissions and economic growth in 38 OECD countries over the period 2010-2022. The purpose of this research is to provide valuable insights for decision-makers, bridging the gap between environmental concerns and economic policies. Employing diverse econometric models, including OLS, fixed effects and random effects, the study rigorously examines the nuanced relationship between carbon emissions and economic well-being. The findings show negative Impact of Carbon Emissions: Contrary to prevailing literature, the study reveals a statistically significant negative impact of carbon dioxide emissions on economic growth (B=-0.12) in OECD countries. The study reveals a general negative trend in carbon dioxide emissions in OECD countries from 2010 to 2022. This suggests a collective effort towards reducing carbon footprints, challenging assumptions of positive trends in carbon dioxide use. The results underscore the complexity of these relationships, urging policymakers to adopt nuanced and region-specific approaches for sustainable and resilient economic development in the face of pressing environmental concerns.

Keywords: *Economic growth, Carbon Dioxide, report, trend.*

****Corresponding Author:*** *Shenaj Haxhimustafa, Faculty of Business and Economics, South East European University, Tetovo, North Macedonia, e-mail: s.daut@seeu.edu.mk*

Received: *3 November 2023;* ***Accepted:*** *28 December 2023;* ***Published:*** *26 January 2024.*

1. Introduction

In the contemporary context of pressing environmental challenges, this paper assumes pivotal significance. In our current world, plagued by a myriad of environmental issues, this paper serves as an indispensable guide for individuals at the helm of economic decision-making-ranging from government officials to economists. Its relevance lies in its potential to offer valuable insights and strategic direction to those who wield influence over economic policies and practices. Given the escalating urgency of addressing environmental concerns, this paper plays a crucial role in steering decision-makers towards informed and responsible choices. Its impact extends beyond immediate economic considerations, transcending into the broader realm of sustainable development and the well-being of both present and future generations. As our global community grapples with the intricate interplay between economic growth and environmental stewardship, the guidance provided in this paper becomes instrumental in fostering a harmonious balance. By offering a roadmap for decision-makers in government and business, it empowers them to make judicious choices that not only promote economic prosperity but also contribute to the creation of a resilient and thriving habitat for the current populace and generations yet to come.

Most of the works and reports carried out by different authors (Mirza & Kanwal, 2017; Du *et al*., 2019; Olubusoye & Musa, 2020; Acaravci & Ozturk, 2010; Akpan, 2012; Jilang & Yu, 2023 etc.) find a positive and statistically significant impact of the increase in carbon dioxide on economic growth. These researches were carried out using different techniques and time periods, according to the analysis presented in these works, in parallel with the increase in the use of carbon dioxide, there was also economic growth, since each business for its operation needs energy and materials various which directly or indirectly contribute to the increase of carbon dioxide. Some of these authors suggest that countries such as China have reached very high levels of carbon dioxide consumption, so they should focus and invest more in green energy such as renewable energy in order to reduce carbon dioxide consumption of carbon while maintaining the pace of economic growth.

In addition to the findings of the positive relationship between carbon dioxide and economic growth, there are other works (Zhang & Cheng, 2009; Saidi & Omri, 2020; Hao *et al*., 2019; Nathaniel *et al*., 2021 etc.) which find a negative relationship and impact of the use of carbon dioxide in economic growth.

In this paper, the study of the interlinked relationship between the use of carbon dioxide and economic growth is presented, using an empirical analysis for 38 OCED countries, that is, an analysis of panel data. The purpose of this paper is to present the impact of carbon dioxide on the economic growth of these countries. Empirical analysis entails the systematic collection and scrutiny of data to derive definitive conclusions. In this study, the focus is on utilizing panel data, which involves longitudinal information from diverse sources, to establish a robust foundation for findings. Through empirical analysis with panel data, the study aims to unravel the intricate dynamics and offer valuable insights into the relationship between carbon emissions and a nation's economic well-being.

The research questions of the paper are:

1. What is the impact of carbon dioxide use and economic growth in OECD countries?

2. What is the trend of carbon dioxide usage in these countries?

In order to examine relationship between carbon emission and economic growth, the following hypotheses were raised:

H1: Carbon emission has a significant effect on economic growth.

H2: OECD countries have positive trends in the use of carbon dioxide.

To evaluate the presented hypotheses, different econometric models were used, starting with the OLS. Since the data used in this study belong to the panel type, three additional models were used: fixed effects method and random effects. The empirical analysis was based on data from reputable sources such as the World Bank, OECD Database and International Energy Agency.

This paper makes a noteworthy contribution by addressing a significant gap in the existing literature. There are no published works to date that comprehensively encompass all 38 member countries of the Organisation for Economic Co-operation and Development (OECD) in the context of the relationship between carbon emissions and economic growth. By extending the analysis to include all OECD nations, this research strives to provide a more comprehensive and nuanced understanding of the intricate interplay between green economic practices and economic prosperity across a diverse array of countries. This broader scope enhances the generalizability and applicability of the findings, offering a more inclusive perspective on the subject matter. The inclusion of all OECD countries ensures that the empirical analysis is not only robust but also representative of a wide range of economic, social and environmental contexts, thus enriching the scholarly discourse on this critical nexus.

The paper is structured into five parts, where the next part presents the review of the literature which contains scientific publications relevant to our research, emphasizing the findings of other authors who have theoretically and empirically examined effect of carbon emission on economic growth. The third part of the study contains methodology, the fourth part presents empirical results and the fifth part includes the conclusions derived from the results.

2. Literature Review

In this part, an empirical review of the literature is presented, which includes the presentation and discussion of the results of findings by different authors who have investigated the relationship between carbon dioxide emissions and economic growth. In this review, the findings and different viewpoints of the authors who have researched this problem for different countries, different periods of time and different methodologies have been presented.

Mirza & Kanwal's (2017) study in Pakistan examines the interplay between economic growth, energy consumption and CO_2 emissions, revealing bidirectional causal relationships. The study recommends Pakistan focus on renewable energy to ensure adequate energy supplies, drawing inspiration from countries like Denmark and Germany. Du et al. (2019) investigate the link between economic growth and carbon emissions in China's construction industry, finding a positive correlation across provinces. The study provides insights for assessing regional construction carbon emissions and strategies for coordinated low-carbon development. Olubusoye & Musa (2020) challenge the Environmental Kuznets Curve hypothesis in 43 African countries, with only 21% supporting the idea that carbon emissions decrease with economic growth. The study suggests implementing renewable energy and carbon mitigation policies. Overall, these articles emphasize the need for tailored, sustainable strategies considering unique regional characteristics to mitigate the environmental impact of economic development.

Acaravci & Ozturk's (2010) study examines the relationships between carbon dioxide emissions, energy consumption and economic growth in nineteen European countries. Using the autoregressive distributed lag (ARDL) bounds testing approach, they find long-run relationships in seven countries: Denmark, Germany, Greece, Iceland, Italy, Portugal and Switzerland. The study supports the Environmental Kuznets Curve (EKC) hypothesis in Denmark and Italy, indicating an inverted U-shaped relationship. Positive long-run elasticity estimates of emissions with respect to energy consumption are observed in several countries. The research provides insights into sustainable development and environmental conservation in the European context, highlighting specific countries with long-run relationships and supporting the EKC hypothesis in Denmark and Italy.

Akpan's (2012) study in Nigeria investigates the relationships between electricity consumption, carbon emissions and economic growth using a Multivariate Vector Error Correction (VECM) framework. The research, based on data from 1970 to 2008, reveals a long-run association between economic growth and increased carbon emissions, indicating a pollution-intensive growth process. Additionally, a rise in electricity consumption corresponds to higher carbon emissions, emphasizing the environmental impact of electricity use. Contrary to the Environmental Kuznets Curve (EKC), there is no evidence that economic growth initially worsens and then improves environmental quality. Granger-causality results suggest a one-way causality from economic growth to carbon emissions, implying that carbon reduction policies can be pursued without hindering economic growth in Nigeria. Importantly, no causality is found between electricity consumption and economic growth, highlighting a crisis in the Nigerian electricity sector. This underscores the need for efficient planning and increased investment in electricity infrastructure to maintain neutrality between electricity consumption and economic growth in Nigeria.

In their 2021 study, Wang and Zhang examined how trade openness influences the decoupling of carbon emissions from economic growth in 182 countries from 1990 to 2015. The results indicate a positive impact of trade openness on decoupling, particularly in high-income and upper-middle-income countries. However, lower-middle-income nations show no significant impact and low-income countries see an increase in carbon emissions with greater trade openness. The study underscores the influence of individual incomes and population growth on the decoupling process, while highlighting the positive contributions of renewable energy and high oil prices. Policy implications stress the need for targeted strategies to achieve decoupling, considering the diverse circumstances of countries with varying income levels.

Gao et al. (2021) study explores the decoupling of provincial energy-related CO_2 emissions from economic growth in China and assesses the challenges and prospects of achieving carbon neutrality by 2060. Using the Tapio decoupling model and Logarithmic Mean Divisia Index model, the research reveals weak decoupling in most provinces, primarily driven by capital investment and total factor productivity. The study breaks down decoupling into relationships between CO_2 emissions and energy consumption and between energy consumption and economic development. Despite provincial variations, there is a converging trend in emissions-economy decoupling, suggesting a coherent low-carbon progress across Chinese provinces. The research provides valuable insights into decoupling dynamics in the context of China's carbon neutrality commitment.

Saidi & Omri's (2020) article investigates the impact of renewable energy on economic growth and carbon emissions in 15 major renewable energy-consuming countries. Utilizing FMOLS and VECM estimation techniques, the study finds that renewable energy effectively boosts economic growth and reduces carbon emissions. The Granger causality test supports a bidirectional causality between economic growth and renewable energy in both short and long runs, validating the feedback hypothesis. Additionally, bidirectional causality is observed between economic growth and CO_2 emissions, while no long-run causal relationship is found between CO_2 emissions and renewable energy.

In another study by Hao et al. (2019), the focus is on the relationship between carbon emissions and economic growth in China. Using the Tapio decoupling model and the environmental Kuznets curve (EKC) framework with panel data from 29 provinces (2007-2016), the results confirm the conventional EKC hypothesis, indicating an inverted U-shaped relationship between carbon emissions and per capita GDP. However, the inflection point is not expected in the near future. The study emphasizes substantial variations in decoupling status among provinces, emphasizing the necessity for tailored environmental regulations and policies based on the economic development and decoupling status of each region.

Nathaniel et al. (2021) study delves into the relationship between CO_2 emissions and economic growth in selected African economies from 1990 to 2014. Utilizing static and dynamic models, the research unveils a positive impact of increased energy use on economic growth, highlighting the energy dependence of African economies. Intriguingly, CO_2 emissions do not show a significant contemporaneous effect but exhibit a noteworthy negative impact with a one-period lag on economic growth. These consistent findings underscore the dual role of trade, contributing to economic growth while adversely affecting the environment in Africa. The study advocates for a transition to clean energy sources in Africa to achieve sustainable economic growth without compromising the environment.

3. Methodology and Data

The empirical investigation spans a 12-year period, encompassing data from 2010 to 2022 and involving 38 countries within the OECD. To assess the influence of carbon emissions on economic growth, four models are employed. Initially, the analysis employs the least squares method (OLS). Recognizing that the research data falls under the panel data category, two additional models tailored for this type of data are executed: one utilizing the fixed effects method and another employing the random effects method.

In a fixed effects model, it is assumed that the impacts of the independent variables remain constant and unchanging across all individuals or units in the sample. Consequently, any disparities observed in the dependent variable are solely attributed to variations in the values of the independent variables. Fixed effects models are commonly employed when researchers aim to draw causal inferences regarding the impact of a specific treatment or intervention. Conversely, a random effects model posits that the effects of the independent variables fluctuate randomly among individuals or units in the sample. This implies that the fluctuations in the dependent variable are attributable not only to differences in the independent variables but also to variations in unobservable factors that differ across individuals. Random effects models find application in situations where researchers seek to generalize their findings to a broader population or when dealing with hierarchical or clustered data structures (Pillai, 2016).

In the process of choosing between a fixed effects model and a random effects model, the Hausman test was employed. The Hausman test serves as a statistical assessment for determining the more suitable model for a given dataset. This test specifically involves comparing the estimated coefficients of the independent variables in both models to ascertain if they exhibit significant differences (Amini *et al*., 2012). A significant difference in coefficients implies that the random effects model is a more fitting choice for the data. Conversely, if the coefficients do not show significant differences, the fixed effects model might be deemed more appropriate. The formula for the test is as follows:

$$H = \left(b_{fe} - b_{re}\right)'\left(V_{re} - V_{fe}\right)^{(-1)\left(b_{fe} - b_{re}\right)} \quad (1)$$

b_fe: represents the coefficient estimates obtained from the fixed effects model.

b_re: represents the coefficient estimates obtained from the random effects model.

V_fe: represents the variance-covariance matrix of the coefficient estimates from the fixed effects model.

V_re: represents variance-covariance matrix of the coefficient estimates from the random effects model.

(b_fe - b_re): This term represents the difference between the coefficient estimates of the fixed effects and random effects models.

(V_re - V_fe)^(-1): This term takes the difference between the variance-covariance matrices of the random effects and fixed effects models and then calculates its inverse.

H: This is the Hausman test statistic. It tests the null hypothesis that the difference in coefficients between the fixed and random effects models is not systematic. If H is statistically significant, it suggests that the fixed effects model is more appropriate than the random effects model.

The Hausman test follows a chi-squared distribution with degrees of freedom equivalent to the number of independent variables. If the computed Hausman statistic surpasses the critical value of the chi-squared distribution at the chosen level of significance, reject the null hypothesis asserting that the coefficients in the two models lack significant differences. Instead, conclude that the random effects model is more suitable. Conversely, if the computed Hausman statistic falls below the critical value of the chi-squared distribution, refrain from rejecting the null hypothesis and deduce that the fixed effects model is more appropriate. The Hausman test operates under the assumption that the random effects model is efficient, indicating that the variance of estimated coefficients in the random effects model is either equal to or smaller than that in the fixed effects model. If this assumption is not fulfilled, the test results may be deemed unreliable (Chmelarova, 2007).

The data were also tested for heteroskedasticity using the Breusch-Pagan test (Martin, 2023) as well as for multicollinearity using the variance inflation factor test (Oke *et al*., 2019).

Model specification:

$$GDP = B0 + B1(CO2C) + B2(EUPC) + B3(EPFRS) + B4(GGE) + B5(ATE) + B6(OC) + B7(PG) + Ui \quad (2)$$

The dependent variable of the study is growth domestic product (GDP), a represents the constant of regression and μ is a constant term. The following are the independent or explanatory variables: carbon emission per capita (CO2C), EUPC is energy use per capita, EPFRS is electricity production from renewable sources, GGE is Greenhouse gas emissions, ATE is access to electricity, OC is oil consumption and PS is population growth.

Table 1. Definition of research variables

Variable	Abbreviation	Unit
Growth domestic product	GDP	%
Carbon dioxide emissions per capita	CO2C	Thousands of tones
Energy use per capita	EUPC	kilowatt-hours (kWh) per person per year
Electricity production from renewable sources	EPFRS	million kWh
Greenhouse gas emissions	GGE	metric tons of carbon dioxide
Access to electricity	ATE	percent of the population
Oil consumption	OC	Thousand barrels per day
Population growth	PS	%

4. Empirical Findings

In this chapter the empirical statistical results are presented, first the results of the descriptive data of the study variables are presented, then the results of the correlation analysis and the results of the econometric models are presented.

Table 2. Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
GDP	494	2.245	3.207	-11.325	24.37
CO2C	493	7.02	3.847	1.22	21.756
EUPC	494	3903.552	2825.034	684.4	18432.32
EPFRS	491	30778.648	64390.417	115	473233.81
GGE	494	440882.81	1265292	2743	12743232
ATE	494	99.927	.342	96.69	100
OC	494	1222.919	3102.496	15	19523
PG	494	.536	.764	-2.26	2.68

Source: Author's Calculation

The data presented in Table 1 provide an overview of the economic, environmental and social dynamics of the 38 OECD countries over the period of 13 years (2010-2022). Each variable reflects a specific aspect of a nation's development, shedding light on trends and patterns that can inform various policy and strategic decisions.

The GDP, with an average of 2.24%, shows the average annual growth rate of the economies of these countries. A positive mean suggests overall economic expansion among the sample nations during this period. CO_2 per capita (CO2C), with an average of 7.02 thousand tons, serves as a metric for an individual's carbon footprint. The relatively low average suggests a collective effort or perhaps a shift towards cleaner energy sources, as lower CO_2 emissions per capita are indicative of a more sustainable and environmentally conscious approach.

Energy use per capita kilowatt (EUPC), which stands at 3903,552 kWh per person per year, provides insight into the energy consumption habits of the sample countries. This figure is essential for evaluating the efficiency of energy use and potential environmental impact. A higher EUPC may signal the need for increased energy efficiency measures and a shift to more renewable energy sources. Electricity Production from Renewable Resources (EPFRS), averaging 30778.648 million kWh, reflects these countries' commitment to sustainable energy practices. A higher average suggests an increased reliance on renewables, contributing to a reduction in carbon emissions and a more resilient energy infrastructure.

Greenhouse gas emissions (GHG), averaging 440,882.81 metric tons of carbon dioxide, is a critical measure of a country's environmental impact. A downward trend in this figure would be consistent with global efforts to combat climate change and reduce high carbon emission rates.

In terms of social welfare, Access to Electricity (ATE), at 99.92%, indicates almost universal access to this essential service. While this is a positive result, attention must be paid to the remaining percentage without access, as universal electrification is an essential aspect of sustainable development. Oil consumption (OC), measured in barrels per day and averaged at 1222,919, provides insight into countries' dependence on fossil fuels.

Reducing this figure can be an essential step towards achieving environmental sustainability and reducing dependence on finite resources.

Population Growth (PG), with an average of 0.53%, indicates the average annual population growth rate. This figure is important for understanding demographic changes and planning for future resource needs.

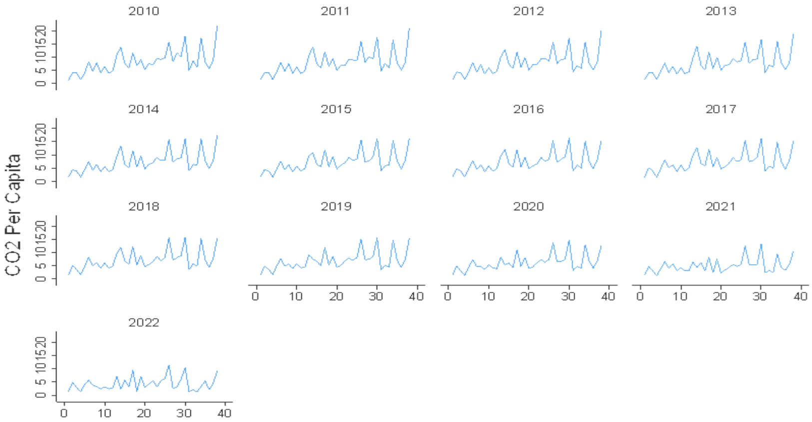

Figure 1. Carbon dioxide emission trend
Note: The data presented includes the 38 OECD countries
Source: Author's Calculation

The figure above shows the results regarding the carbon dioxide emission trends in the 38 OECD countries. According to the results presented in this figure, we see that in general from 2010 to 2022 the trend of carbon dioxide emissions in the 38 OECD countries is negative.

Table 3. Correlation analysis

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) GDP	1.00							
(2) CO2C	-0.64	1.00						
(3) EUPC	0.04	0.39	1.00					
(4) EPFRS	0.39	0.25	0.09	1.00				
(5) GGE	-0.02	0.30	0.10	0.70	1.00			
(6) ATE	-0.09	0.26	0.22	0.08	0.03	1.00		
(7) OC	-0.04	0.30	0.15	0.86	0.79	0.03	1.00	
(8) PG	0.12	0.22	0.24	-0.07	-0.03	-0.17	0.00	1.000

Source: Author's Calculation

The table above presents the results of the correlation analysis, according to the results presented in the table above, economic growth has a strong negative relationship with carbon dioxide emissions (r=-0.64), so the increase in the use of carbon emissions has a negative impact on economic growth in the 38 OECD countries. On the other hand, the use of electricity from renewable sources has a positive relationship with economic growth (r=0.39).

The table above presents the summarized results of the presented econometric models, taking into account the result of the Hausman test (0.9670), we consider that the difference in the coefficient is not systematic and in this case we prefer the model with random effects as a model with more reliable results. In the variables of the study, the problem of multicollinearity based on the variance inflation factor (2.58) does not appear, while the data are homoscedastic based on the Breusch Pagan Langargian test (0.4209). The results of the random effects model are presented below.

Table 4. Results of econometric models

Variables/Models	OLS	FE	RE
CO2C	-0.404	-0.548**	-0.127***
	(-0.87)	(-2.15)	(-6.33)
EUPC	-0.05	-0.05**	0.305**
	(-1.02)	(-2.71)	(-3.56)
EPFRS	-0.104**	-0.937**	0.952**
	(-2.20)	(-2.54)	(-2.46)
GGE	0.07	-0.08	-0.08
	-0.58	(-0.65)	(-0.37)
ATE	0.373*	0.423**	0.409**
	(-1.91)	(-3.18)	(-4.09)
OC	0.132	0.17	0.163
	-1.13	-1.9	-1.72
PG	0.538**	0.613***	0.599***
	-2.6	-3.86	-3.59
_cons	39.84	44.67	43.29
	-0.86	-1.25	-1.16
N	490	490	490
R-squared	54.6	69.2	68.9
F-test	0.0121	0.0000	0.0001
Hausman Test	0.9670		
Hettest	0.4209		
VIF	2.58		

Note: Significant Levels: * p<0.1, ** p<0.05, *** p<0 0.01
Source: Author's Calculation

The emission of carbon dioxide has a negative impact on the economic growth (B=-0.12) of the OECD countries, so for every 1 ton more of carbon dioxide there will be an economic decline of 0.12% on average. This coefficient is statistically significant at the 1% significance level (P < 0.01).

The impact of energy use is positive on economic growth (B=0.30), so for every 1 kWh more in the use of electricity, there will be economic growth of 0.30% on average. This coefficient is statistically significant at the 5% significance level (P<0.05). The production of energy from renewable sources also has a positive impact on economic growth (B=0.95), so for every 1 million kWh produced in electricity from renewable sources, there will be an average economic growth of 0.95%, this coefficient is also statistically significant (P<0.05). Access to electricity, also a variable related to electricity, has a positive impact (B=0.40) on economic growth.

The last variable presented, population growth, has a positive impact (B=0.59) on economic growth. So, for every 1% increase in the population, there will be an economic growth of 0.59% on average. The coefficient is statistically significant at the 1% significance level ($P < 0.01$).

4. Discussion

The presented results of the econometric models examining the relationship between carbon emissions, energy consumption and economic growth in OECD countries offer valuable insights that can be compared and contrasted with findings from the literature.

Starting with the impact of carbon dioxide emissions on economic growth, the obtained result indicates a negative relationship (B = -0.12), implying that an increase in carbon emissions is associated with a decline in economic growth. This finding is in contrast to some of the literature reviewed, particularly the studies by Mirza & Kanwal (2017) on Pakistan and Nathaniel *et al*. (2021) on selected African economies. Mirza and Kanwal found bidirectional causal relationships between energy consumption, economic growth and CO_2 emissions in Pakistan, suggesting a more intricate dynamic. On the other hand, Nathaniel *et al*. (2021) reported a significant and positive effect of increased energy use on economic growth in African economies, emphasizing the energy dependence of economic growth in that context.

Moving on to energy use, the result indicates a positive impact on economic growth (B =0.30). This aligns with the findings from several literature sources, including the study by Akpan (2012) on Nigeria, where an increase in electricity consumption was associated with economic growth. Similarly, the study by Acaravci & Ozturk (2010) on European countries found positive long-run elasticity estimates of emissions concerning energy consumption in several countries, supporting the idea that energy use contributes to economic growth.

The positive impact of energy production from renewable sources on economic growth (B = 0.95) is consistent with the literature, such as the research by Du *et al*. (2019) on China's construction industry. Du *et al*. emphasized the importance of renewable energy in the spatial distribution of carbon emissions and economic development, supporting the idea that incorporating renewable sources into the energy mix can contribute to economic growth.

Access to electricity, as a variable related to energy, also exhibits a positive impact on economic growth (B = 0.40). This aligns with the findings of Akpan (2012), who emphasized the importance of efficient planning and increased investment in electricity infrastructure development for economic growth in Nigeria.

Population growth is another variable showing a positive impact on economic growth (B = 0.59), consistent with the literature, particularly the studies by Du *et al*. (2019) on China and Acaravci & Ozturk (2010) on European countries. These studies acknowledged the role of population growth in the complex interplay among carbon emissions, energy consumption and economic growth.

While there are consistencies between the presented results and findings from the literature, some discrepancies exist. The negative impact of carbon dioxide emissions on economic growth contradicts the literature in some instances, suggesting that the relationship between these variables may vary across different regions and contexts. Additionally, the positive impacts of energy use, renewable energy production, access to electricity and population growth on economic growth align with the literature, reinforcing the importance of energy-related factors and demographic dynamics in economic development. The disparities highlight the complexity of these relationships and emphasize the need for region-specific analyses and policies to address the unique characteristics of each context.

H1: Carbon emission has a significant effect on economic growth - the regression analysis results show a statistically significant negative impact of carbon dioxide emissions on economic growth in the 38 OECD countries ($P < 0.01$). This finding aligns with the hypothesis.

H2: OECD countries have positive trends in the use of carbon dioxide - contrary to the hypothesis, the figure illustrating carbon dioxide emission trends in the 38 OECD countries from 2010 to 2022 depicts a general negative trend. This implies that, on average, the OECD countries have been reducing their carbon dioxide emissions over the specified period rather than increasing them. Therefore, results do not support the hypothesis that OECD countries have positive trends in the use of carbon dioxide.

5. Conclusions

This paper undertook a comprehensive analysis of the interlinked relationship between carbon dioxide emissions and economic growth in 38 OECD countries over a 12-year period (2010-2022). The study employed various econometric models, including OLS, fixed effects and random effects, to explore the nuanced dynamics of this relationship. The empirical findings shed light on crucial insights with implications for environmental policies and economic decision-making.

The average annual growth rate of the economies, as measured by GDP, was found to be 2.24%, indicating an overall economic expansion among the sample nations during the study period. However, the carbon footprint per capita, represented by CO_2 emissions, exhibited a relatively low average of 7.02 thousand tons, suggesting a potential shift towards cleaner energy sources and a more environmentally conscious approach.

Contrary to some existing literature, the study revealed a statistically significant negative impact of carbon dioxide emissions on economic growth ($B = -0.12$) in the OECD countries. This result challenges the notion of a universally positive relationship between carbon emissions and economic growth, emphasizing the need for nuanced and region-specific analyses.

On the positive side, the study confirmed the expected positive impact of energy use, energy production from renewable sources and access to electricity and population growth on economic growth. These findings align with existing literature, emphasizing the importance of energy-related factors and demographic dynamics in fostering economic development.

The disparities between the presented results and some findings from the literature underscore the complexity of the relationships between carbon emissions, energy consumption and economic growth. While the negative impact of carbon emissions on economic growth contradicts some literature, the positive impacts of energy-related variables and population growth reinforce the multifaceted nature of these dynamics.

Additionally, the hypothesis testing revealed that OECD countries, contrary to the initial assumption, have been experiencing a general negative trend in carbon dioxide emissions from 2010 to 2022. This indicates a collective effort among these nations to reduce carbon emissions, challenging the assumption of positive trends in carbon dioxide use.

In light of these findings, policymakers, government officials and economists should consider the potential negative consequences of high carbon emissions on economic growth. Moreover, the emphasis on renewable energy sources, improved access to electricity and managing population growth can be pivotal in fostering sustainable economic development while addressing environmental concerns.

In conclusion, this study contributes valuable insights into the complex relationship between carbon emissions and economic growth, urging a holistic approach to environmental and economic policies for a sustainable and resilient future.

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