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Global dynamics of environmental Kuznets curve and fishing grounds load capacity: A cross-correlation analysis of income and CO2 emission and marine ecosystem: Cross-section data econometrics

Ettayib MEZOURI
Faculty of Economics, University of Relizane, Algeria
https://orcid.org/0000-0003-0332-0213
Email: ettayib.mezouri@univ-relizane.dz

Mourad BENIANI
Faculty of Economics, University of Ain Temouchent, BELHADJ Bouchaib, Algeria
https://orcid.org/0009-0008-3713-0382
Email: mourad.beniani@univ-temouchent.edu.dz

***Abstract*---**Changes in the environment and distortions place nations under socioeconomic strain on a global scale, making them a crucial topic of debate, which makes them an important issue of discussion. Researchers and academics in this field, state that advancements in transportation, capture and storage, nutritional properties, and long-distance exportability are some of the factors contributing to the notable declines in marine biodiversity. In this context, this paper analyzes the nexus among the ecological footprint as a multi-aspect indicator of environmental degradation, marine ecosystem, economic growth, energies uses, and climate policy uncertainty within the Environmental Kuznets Curve (EKC) hypothesis and Fishing Grounds Load Capacity Curve (FGLCC) hypothesis, framework for two panels of developing countries (D10) and developed countries (G10) during 2000–2024. Thus, this study takes into account the underappreciated component of the marine supply side, which sets it apart from other research that just looked at the demand side through fishing footprints. According to the pooled mean group (PMG), estimation results indicate an inverted U-shape nexus among the economic growth and ecological footprint, which implies validation of the EKC hypothesis in developing countries (D10) and developed countries

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Corresponding author*: Mezouri, E., Email: ettayib.mezouri@univ-relizane.dz*
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(G10). In addition, the findings indicate the positive impact of climate policy uncertainty and the energies uses on the environment in all two panels.More importantly, The Fishing Grounds Load Capacity Curve (FGLCC) hypothesis is valid only in the case of developed countries and is not valid in developing countries. Additionally, the results demonstrate that energies uses, fisheries production and climate policy uncertainty have a positive impact on the marine ecosystem.finally, The findings of the Dumitrescu–Hurlin panel causality test also indicate the existence of bidirectional causality between energy consumption and CO2 emissions in all two panels of countries, and between economic growth and marine ecosystem in the developed countries (G10).Finally, these results give decision-makers important information that helps them pinpoint important factors that support the conservation of marine variety.

***Keywords*---**Fisheries Production, FGLCC hypothesis, EKC hypothesis, PMG-Panel ARDL, D–H Panel Causality, D10 and G10 countries.
JEL Codes: C33, Q01, Q20, Q50

1. Introduction

There is growing concern about the unrelenting increase in emissions and the resulting impact on the global warming phenomenon. The research has nearly come to the conclusion that economic expansion and activity play a major role in environmental degradation. Although there are many research on the relationship between economic growth and environmental degradation, there aren't many empirical studies looking at the opposite relationship, that is, how environmental degradation influences economic growth. But according to the related research, environmental deterioration increases when economic expansion is achieved (Alex O & Eric Evans, 2023). Some studies have found that economic expansion is black blood. that has always run through the veins of the global environment is pollution, which is still a major factor in climate change. Since the industrial revolution, human activity has greatly increased global temperatures, leading to a number of environmental issues like biodiversity loss, glacier melting, ocean and sea surface warming, and floods and droughts in many parts of the world. This has certainly put pressure on policymakers to act since pollution have always fluctuated. Thus, a battery of literature focuses on the potential impact of pollution on environmental. Like the influence of human actions on ecosystems (Wei et al., 2023; Parker and Tyedmers, 2012), the Industrialization, urbanization, over-consumption of natural resources, and a dependence on non-renewable energy are the primary causes of these degradations (Wu et al., 2018, Sahoo and Sethi, 2021), energy consumption and burning of fossil energy significantly contributes to global warming and climate change (Farooq et al., 2019; Ontario, 2007), offshore oil platforms(Bergmo & Holt, 2024), economic activities(Chao & al, 2022), Overall, these studies reveal that Environmental pollution of all kinds have detrimental effects on climate change in countries.

To explain the causes of environmental degradation, One outstanding approach, is the Environmental Kuznets Curve (EKC) hypothesis suggests an inverted U-shaped relationship between environmental pollution and economic growth, with pollution increasing in early stages and decreasing as per capita income peaks, supporting the hypothesis in low-income economies. The EKC hypothesis, which suggests that environmental pollution is linked to economic growth, has been tested using various econometric techniques. Empiricalstudies (Apergis and Ozturk, 2015, Aslan et al., 2018, Bilgili et al., 2016, Chang, 2009, Destek et al., 2018, Lee et al., 2010, López-Menéndez et al., 2014, Markandya et al., 2006, Shahbaz et al., 2013; Al-Mulali et al. 2015; Destek et al. 2018), have shown its validity using various environmental pollution indicators, such as CO2 emissions, ecological footprint, and water pollution rate. However, some argue that using ecological footprints instead of CO2 emissions is more appropriate for testing the relationship between environmental pollution and economic growth. In this context, There are other studies There are other studies that have shown that the Environmental Kuznets Curve (Dasgupta et al., 2002; Dinda, 2004; Frodyma et al., 2022; Ayad et al., 2023a; Uche et al., 2023; Boukhelkhal, 2022; Wang et al., 2023a). Balado-Naves et al. 2018; Ozcan & Ulucak 2021; Altıntaş & Kassouri 2020), Farooq et al. 2022; Wang et al. 2023b). suggests pollution increases during early development and industrialization due to economic gains, but as incomes rise, societies can reduce emissions through innovation, environmental laws, and technological progress.

In this context, most papers use CO2 emissions and ecological footprints as ecological indices, but these only measure the demand side of the environment. Accordingly, the present research takes into account the underappreciated component of the marine supply side, which sets it apart from other research that just looked at the demand side through fishing footprints. The Load Capacity Curve hypothesis, a novel approach to the Environmental Kuznets Curve paradigm, was established by Pata and Kartal (2023) by examining the immediate and long-term consequences of income throughout development and industrialization. According to a review of existing literature, recent studies have shown how to use the load capacity factor as an indicator of environmental pollution (Caglar et al., 2023b; Destek et al., 2023a); Huang et al., 2023; Yang et al., 2023). (Li and others, 2023a) The biocapacity index, which provides information on the supply and demand sides of environmental assets, was presented by Siche et al. (2010) in the same context (Dogan and Pata, 2022). The relationship between economic growth and environmental quality is investigated using the load capacity factor. A U-shaped pattern indicates that wealth and the load capacity factor may be related, and that higher-income nations may be able to increase their biocapacity. This implies that resolving supply-side environmental issues and satisfying demand can reduce environmental contamination.

In the case (Ayad, 2023)explored the economic variables' impact on marine states can be inaccuracies if only fishing footprints are studied. The EKC approach assumes the biocapacity index to be constant, neglecting changes in natural resource supply. This raises concerns about the credibility of results. The Load Capacity Curve hypothesis framework addresses this limitation by incorporating supply side changes, allowing for a more precise determination of the turning point. This approach is applicable to all environmental aspects, including marine, forests, grazing lands, and built-up land. It provides a comprehensive understanding of the complex interactions between economic development and environmental sustainability. Climate change is without a doubt the most significant hazard to the social and economic well-being of humanity in the new millennium. In this context, Many countries worldwide, including the developed and developing countries, are diligently striving to protect their environments. One of the most popular strategies they have used to do this is the implementation of protected areas. Since there exists a strong disparity in the socioeconomic development levels across developed (G10) and developing (D10) countries, this creates a research gap for empirical analysis and comparison of these two groups of countries to examine the real effects in the specific condition of these countries. In short, the existing literature on nexus between income levels and environmental under the LCC and EKC hypotheses. gives rise to the followingresearch questions. Does income have similar behavior in both (G10) and (D10) countries ir respectiveof having a different level of economic development? Is the relationship between income and environmental degradation U-shaped in both developed (G10) and developing (D10) countries? Does the The LCC and EKC hypotheses are validated in both developed (G10) and developing (D10) countries? To answer the above research questions, following are specific objective of the study:

- ✓ To investigate the casual relationship between income and CO2 emissions and to estimate and testing the environmental kuznets curve hypothesis in Developed countries (G10) and Developing countries (D10).
- ✓ To investigates the impact of income on the marine condition in Developed countries (G10) and Developing countries (D10) by exploring the U-shaped relationship between income and the Fishing Grounds Load Capacity Factor.

Our empirical approach is based on new advances in non-stationary panel data econometrics that allow us to take potential cross-sectional dependence between nations into account. The Pooled-Mean Group (PMG) estimator of Pesaran, Shin, and Smith (1999) based on the estimation of an Autoregressive Distributed Lag (ARDL) model is used to model the short- and long-term relationships between study variables and hypothesis testing. The Dumitrescu–Hurlin panel causality test is used to ascertain which direction the independent variables and the dependent variable were causally related. The remainder of the paper is structured as follows: Section 2 presents the literature review. Section 3 depicts the specification of the methodologies. Section 4 describes the data. Section 5 presents the findings of the study. Section 6 provides a discussion of the results in the context of the Algerian economy. Finally, Section 7 concludes the study.

2. Conceptual framework of the EKC and FGLCC hypothesises

This empirical analysis examines a novel hypothesis, the load capacity curve (LCC) hypothesis, in contrast to the environmental Kuznets curve (EKC) hypothesis, which is frequently examined in this context. Consequently, this part will provide a detailed explanation of the LCC and EKC hypotheses.

2.1. Conceptual framework, originsand shape of the EKC curve

In the early 1990s, economics focused on the idea that being poor was insufficient for environmental improvement. Beckerman's theory suggests that economic growth can lead to environmental degradation, but becoming rich is the best way to achieve a decent environment. The World Development Report in 1992 emphasized the aggravated environmental problems caused by economic activity, and theoretical research on the EKC is presented (Leal & Marques, 2022). Through the groundbreaking work of (Grossman & Krueger, 1991), conducted in 1991, the EKC gained significant attention from policymakers, theorists, and empirical researchers and began to be widely employed in environmental studies. They found that, similar to (Kuznets, 1995) link between income per capita and income inequality, the association between environmental degradation and income per capita similarly exhibits an inverted U-shaped curve.

Precisely, The Environmental Quality Control (EKC) hypothesis has been studied in various countries and regions, with some finding support and others finding no support. The EKC hypothesis has been supported in 38 developed and developing countries, Pakistan, France, ASEAN-5 countries, South Africa, 28 European countries, the UK, China, 68 countries, MENA region, 20 sub-Saharan countries, USA, EU-5 countries, and 16 MENA countries. However, some studies in Italy, Australia, and G-6 countries did not find support for the EKC hypothesis. Some studies found mixed results, with some showing a U-shaped EKC for low-income groups, while others found support for high-globalized countries but not low-globalized countries. Finally, The EKC hypothesis suggests that economic growth and environmental deterioration are interconnected, with economic growth having a negative impact on environmental quality. The relationship between economic growth and environmental deterioration is influenced by scale, composition, and technical effects. As the economy grows, it increases demand for natural resources, leading to industrial waste and negative environmental effects. Policymakers often overlook this, leading to increased environmental deterioration. As the economy becomes more productive, it shifts from capital-intensive to knowledge-intensive, investing in research and development, and replacing old technologies with environmentally friendly ones. This relationship results in a bell shape or inverted U-shape, indicating a simultaneous increase in both economic growth and environmental quality.So, in short, The environmental Kuznets curve (EKC) hypothesis suggests that economic growth leads to rapid environmental degradation due to pollution, which slows down with increased income levels (AlKhars & al, 2022).Figure 01 explains the environmental Kuznets curve (EKC) hypothesis presented by (Kuznets, 1995).

2.2. Conceptual framework, originsand shape of the FGLCC curve

Increasing ecological problems, externalities at the micro level, and the sustainability of economic growth at the macro level have put this issue on the agenda. CO2 emissions and the ecological footprint have been utilized as ecological indices in most of the research in this topic. These metrics, however, solely account for the environment's demand side. The ecological footprint is a representation of the environmental impact of human demand for natural resources, whereas CO2 emissions are a reflection of air pollution. In order to address the availability of resources and the supply side of environmental assets, Despite the environmental Kuznets curve hypothesis, which is often analyzed in this context, this empirical analysis investigates a new one that of the load capacity factorhypothesis. Moreover, The load capacity factor framework is applicable to all environmental aspects, including marine, forests, grazing lands, and built-up land. It integrates supply side interactions, providing comprehensive understanding of economic development and environmental sustainability, enabling informed policymaking for marine ecosystem health.

In this context, (Solarin & Bello, 2018) and (Wu & al, 2019) state that CO2 may not be sufficient to capture and analyze the full spectrum of global ecological degradation. To address this shortcoming, (Wackernagel & Rees, 1996) developed a natural resource calculation tool, the ecological footprint, to measure environmental sustainability. ecological footprint shows how much biologically productive environ is required to produce all demanded resources and repair environmental damage. ecological footprint measures the biological area required to meet all needs in global hectares. (Siche & al, 2010) proposed a novel index, the biocapacity index, as an environmental health measure. To obtain a more comprehensive understanding of the environmental condition, the authors introduced the Load Capacity Factor by dividing the biocapacity index by the ecological footprint. Through the above mentioned, This indicator is a more comprehensive measure than CO2 emissions because it consists of a combination of footprints. However, The load capacity factor is an indicator that measures the ecological system's ability to cope with environmental degradation, considering both supply and demand aspects of nature. It is calculated as the ratio of biocapacity to ecological footprint, indicating that if the load capacity factor value is equal to or greater than 1, the environmental conditions are sustainable. Conversely, a decrease in the Load Capacity Factor index below 1 suggests that the biocapacity is inadequate to cope with emissions, resulting in a lack of environmental sustainability.

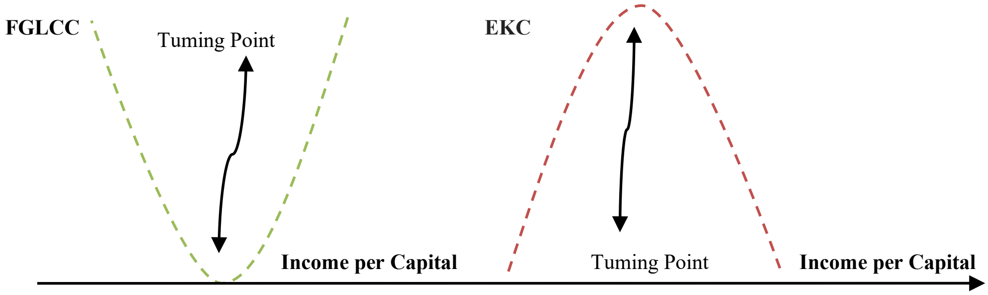

Figure 01. Graphical representation of the FGLCC hypotheses and the EKC hypotheses
Source: Prepared by the researcher based on World Bank data, 2024

In Figure 01, The EKC curve implies an increasing relationship between income levels and environmental pollutants in the early stages of economic growth. The EKC defines the trajectory of pollution over time and the revenue that results from economic progress. It is comprised of an inverted U-shaped curve that connects income with environmental degradation. The idea behind the EKC is long-term. Given this, the EKC represents a dynamic link between the economy and the environment that focuses on long-term transformation processes. The type of the income's impact on environmental deterioration and its square (to guarantee the curve's concavity) are used to evaluate the EKC. The substantial and positive coefficient and elasticity of income, as well as the significant and negative coefficient and elasticity of income squared, justify the inverted U-shaped curve. In Figure 01, FGLCC curve, which implies that fishing load capacity (biocapacity of fishing areas divided by the footprint on those areas) first decreases with rising per capita income and then increases above a certain level of wealth. Also, the green curve indicates that there is an inverse decreasing relationship between environment and income level since FGLCC is an indicator of environmental quality, and after reaching a certain level of prosperity, an increase in income may play a role in improving FGLCC.

3. Literature review

The theoretical investigation of Kuznets's (EKC hypothesis) in 1955 is examined in this part. And according to the Fishing Grounds Load Capacity Curve (FGLCC) hypothesis, which was proposed by Pata and Kartal's counterpart in 2023, this indicator provides a broader perspective of the condition of the marine environment by considering both the demand side (fishing footprint) and the supply side (marine biocapacity), which only considers the connection between marine conditions and economic growth.

3.1. Environmental Kuznets curve (EKC)

The relationship between economic growth and environmental quality has been studied since the 1990s, initially derived from Simon Kuznets' 1955 work. Environmental economists postulated the relationship between income growth and environmental degradation, with (Grossman & Krueger, 1991), confirming an upward trend of pollutants as per capita income increased, and Shafik and Bandyopadhyay demonstrating a U-shaped relationship between environmental pollution and economic growth. Panayotou's Environmental Kuznets Curve (EKC) confirmed the inverted-U-shaped relationship in both developing and developed countries. (Beckerman, 1992), argued that economic growth often leads to environmental degradation, but wealth is the best and likely only way to achieve a decent environment in most countries. (Chiu Y, 2012) examined the EKC for 52 developing nations between 1972 and 2003 using the PSTR model. Arable land area, real GDP per capita, rural population density, trade openness, and political freedom are some of the variables that were examined in this study. They discovered a substantial threshold impact between deforestation and GDP as well as an EKC link for deforestation. They demonstrated that 3,021 and 3,103 million dollars marked the turning points.Study by (Heidari & al, 2015) found that economic growth in ASEAN countries increases environmental degradation, while energy consumption increases CO2 emissions, supporting the EKC hypothesis, and contrasting with GDP per capita levels above 4,686 million dollars.

(Aye & al, 2017) study found a U-shaped relationship between economic growth, CO2 emission, energy consumption, and financial development in 31 developing countries. Economic growth negatively impacts CO2 emissions in low growth regimes but positively in high growth regimes. The findings suggest a need for low carbon technologies to reduce emissions and promote sustainable economic growth, including energy efficiency and renewable energy. (Sisay Demissew & Balázs, 2020) This study tested the environmental Kuznets curve (EKC) hypothesis for 12 East African countries from 1990 to 2013. Results showed a bell-shaped relationship between per capita income and CO2 emissions, suggesting that economic activities do not lead to environmental degradation. To reduce CO2 emissions, environmental conservation policies, technological advancements, and modern industrial policies are needed. (Khan, 2021), study investigates the Environmental Kuznets Curve (EKC) in the USA, considering macroeconomic variables like economic growth, institutional quality, globalization, energy consumption, financial development, urbanization, and remittance. Results show economic growth positively impacts environmental degradation, while financial development, energy consumption, globalization, and urbanization reduce it. Institutional quality improves environmental quality by reducing CO2 emissions.

According to (Yuanyuan & al, 2022) explores the impact of nuclear energy consumption on environmental sustainability in BRICS countries during 1985-2020. It suggests that economic growth exacerbates environmental pollution, while nuclear and renewable energy consumption improve environmental quality. Panel Granger causality tests show a bi-directional causality between CO2 emissions and renewable energy consumption with economic growth and inverted U-shaped environmental Kuznets curve hypothesis is verified. (Mucahit & al, 2023) study examines the impact of renewable energy consumption, energy investments, and green patents on the ecological footprint in European Union countries. The findings indicate that the EKC hypothesis is exclusively true in Finland. Conversely, the Netherlands and Austria have smaller ecological footprints due to their use of renewable energy, whereas Germany and Italy have larger ecological footprints. Energy investments raise the ecological footprint in Austria, Denmark, Finland, and the Netherlands, whereas green patents decrease it in Italy and increase it in Germany, Finland, and the Netherlands. (Alfian & Budiono, 2023) this study confirms the EKC hypothesis's validity on Indonesian carbon dioxide emissions using the Autoregressive Distributed Lags model. It reveals that income, fossil energy consumption, renewable energy, and forest moratoriums increase emissions simultaneously, contradicting the EKC hypothesis. The research emphasizes the need for renewable energy use and forest conservation.

(Hakan & al, 2023) study examines the relationship between environmental degradation, economic growth, trade openness, primary energy consumption, coal consumption, and hydroelectricity consumption in Turkey from 1971 to 2015. Results show that trade openness increases CO2 emissions but decreases ecological footprint. Coal consumption increases emissions and footprint, while hydroelectric energy reduces emissions but has no environmental impact. The study emphasizes the importance of renewable energy use and transitioning from coal consumption for future energy diversification in Turkey.The findings show that Turkey's ecological footprint and CO2 emissions support the EKC concept.(Fortune, 2023)study's main goal is to investigate the situation of South Africa, one of the continent's most notable instances of a highly developed industrialized economy. The purpose of this study is to investigate South Africa's

capacity to cut emissions brought on by human activity. For this reason, the autoregressive distributed lag (ARDL) techniques are used in this work.The results of the study show that, when the factors under investigation are taken into account in both short- and long-term situations, there exists both the U-shaped curve and the inverted U-shaped EKC. On the bases of above discussion, we hypothesize that:
H1; *An inverted U-shape nexus among the economic growth and ecological footprint, a prerequisite for the realization of the EKC hypothesis.*

3.2. Fishing Grounds Load Capacity Curve (FGLCC)

In environmental quality research, many parameters are used as indicators of environmental pollution. Environmental pollution can no longer be accurately represented by carbon emissions alone, as has been increasingly recognized in recent years (Solarin S. , 2019).Furthermore, there is mistrust for these indicators because, when calculating ecological footprints and environmental methods, they do not take into consideration nature's capacity to meet demand (supply-side environmental concerns) (Siche & al, 2010). According to (Clark & al, 2018) the study explores socio-structural factors influencing nations' fisheries footprint and seafood consumption. It finds that economic development, population size, and food-system changes account for ecological impacts and seafood consumption. The study also shows that modernization and changing food systems have increased impacts on seafood consumption and aquatic ecosystems, particularly in the context of protein-intensive diets.Using the fishing grounds footprint as a measure of environmental deterioration in China from 1961 to 2017, this study examines the viability of the environmental Kuznets curve (EKC) hypothesis. China's overall fisheries production is also used in the study as a control variable. Given that the analysis's findings point to a long-term relationship between the variables, we estimate the long- and short-term coefficients that support the long-term validity of the EKC. We discover that the environment is negatively impacted by the entire productivity of fisheries.The findings from the research have significant policy implications for decision-makers. Using new, environmentally safe technologies throughout the whole fishery production process and enacting a common fishing policy at the regional and global levels to stabilize the FGF may both be good for the environment (Veli & al, 2022).

(Sajjad & al, 2022) this research examines economic factors impacting the ecological footprint in the Asia-Pacific fishing sector, focusing on nine economic freedom indicators and control variables from 2000-2017. The load capacity curve (FGLCC) hypothesis confirms GDP per capita growth positively affects fishing grounds footprint, while other control variables like natural resource rents, urbanization, and energy intensity do not. Economic freedom components, such as Government Integrity, Tax Burden, Business Freedom, and Monetary Freedom, increase fishing footprints. Trade and investment freedom have negative effects on fishing footprints, while reducing pressure on aquatic resources. (Destek & al, 2024) has demonstrated the use of LCF as an EQ indicator in the context of the body of literature when examining the relationship between economic growth, which is widely recognized as one of the most important factors affecting the quality of the environment (Caglar & al, 2023; Destek b & al, 2023) explores China's environmental quality, focusing on competitive industrial performance, economic growth, and renewable energy consumption. It reveals that industrial competitiveness affects environmental quality, invalidating the load capacity curve hypothesis. Renewable energy also contributes to environmental quality. The study suggests that China's sustainable development policies should focus on increasing high-tech activities in manufacturing and renewable energy use, while preserving rapid growth and competitive advantage in the industrial process.

(Zafer & al, 2023) this study examines the fishing grounds footprint per capita of 10 countries producing and catching the most fish. It examines stochastic behaviors using traditional, residual augmented, and Fourier unit root tests. The results will help policymakers develop inclusive strategies for marine animals and ecological life, as resources will likely be needed to meet the growing population's needs. According to (Ayad, 2023) explores the impact of income on the marine ecosystem in G7 nations from 1970 to 2019, focusing on the U-shaped relationship between income and the Fishing Grounds Load Capacity Factor. It also examines renewable energies and human capital's influence on the marine environment, revealing a positive relationship with renewable energy and population.Accordingly, load capacity factor, which indicates environmental quality, reduces in the first phases of income but rises again after output levels reach a threshold value. According to this, the relationship between the two parameters is that countries that reach a certain income level may have the opportunity to increase their biocapacity (Li et al., 2023). In this context (Caglar & al, 2024) The study examines the impact of clean energy technologies on environmental quality in Turkiye, using the load capacity curve hypothesis and the Augmented ARDL with Fourier terms approach. Results show income supports environmental quality, while human capital improves it. However, clean energy technologies are insufficient for Turkiye, highlighting the need for increased investments in sustainable energy security. (Ayad & al, 2024) a study examining economic freedom and human capital impacts on fishing grounds footprint in GCC countries between 2000 and 2021 found a Marine Environmental Kuznets Curve, with a turning point of $38,177 per capita. Improved human capital contributes to long-term sustainability, while economic freedom has negative effects.On the bases of above discussion, we hypothesize that:
H2*; An inverted U-shape nexus among the economic growth and (biocapacity of fishing areas divided by the footprint on those areas), a prerequisite for the realization of the FGLCC hypothesis.*

The purpose of this research article is to analyzes the nexus among the ecological footprint as a multi-aspect indicator of environmental degradation, marine ecosystem, economic growth, energies uses, and climate policy uncertainty within the Environmental Kuznets Curve (EKC) hypothesis and Fishing Grounds Load Capacity Curve (FGLCC) hypothesis, framework for two panels of developing countries (D10) and developed countries (G10) during 2000–2023. pooled mean group (PMG) estimation is utilized to investigate the environmental Kuznets curve hypothesis and fishing grounds load capacity in developing countries (D10) and developed countries (G10). This research article fills the following important research gaps that remain uncharted in existing researches.

First, it adds to the growing body of empirical investigations on the determinants of reducing CO2 emissions while attaining economic growth, especially to the literature studying the impact of economic growth on environmental degradation. Second, In order to evaluate marine ecosystems, prior research has mostly concentrated on environmental indicators like CO2 emissions, ecological footprints, load capacity factor, or fishing footprints. However, by concentrating on the Fishing Grounds Load Capacity Factor for the first time, this study presents a fresh method.Third, This empirical analysis examines a novel hypothesis, the Fishing Grounds Load Capacity Factor hypothesis, in contrast to the environmental Kuznets curve (EKC) hypothesis, which is frequently examined in this context. Fourth, this research endeavors to scrutinize the impact of essential variables on the maritime environment. In addition to economic growth, the study includes the variables of energy consumption, population density and fisheries production, which are expected to have contrasting effects, as well as the climate policy uncertainty.Fourth, to the best of our knowledge, this work is the first attempt to use the environmental Kuznets curve hypothesis and fishing grounds load capacity to evaluate the marine environmental status of developing countries (D10) and developed countries (G10). Prior research has mostly concentrated on certain regions, including the Asia-Pacific (Sajjad et al., 2022), the GCC countries (AlKhars et al., 2022), the European Union countries (Mucahit et al., 2023), the G7 countries (Ayad, 2023), and Turkiye (Caglar et al., 2024). Surprisingly, the developed countries (G10) and developing countries (D10) are being compared because their levels of industrialization and development are different.have received little attention, even though they have a big influence on the environment and the world economy.

In brief, in order to address these issues, this study intends to close the existing gaps by concentrating on the Developing Countries (D10) and Developed Countries (G10) marine ecosystem, proposing the new Fishing Grounds Load Capacity Factor (FGLCF), and investigating the sustainability of the marine ecosystem from a comprehensive viewpoint that takes into account both the supply and demand aspects of marine resources. Additionally, this study examines the relationship between income and the health of marine ecosystems by following the Fishing Grounds Load Capacity Curve (FGLCC) theory put forth by Ayad (2023) and Pata et al. (2023). Additionally, investigates the relationship between income and environmental degradation by analyzing the possible effects of economic growth on CO2 emissions in Developing Countries (D10) and Developed Countries (G10) using the inverted U-curve relationship of the environmental Kuznets curve (EKC) hypothesis presented by Grossman & Krueger (1991) and Kuznets (1995).

In addition, to our knowledge, this is the first study to simultaneously analyze the tests whether there is a U-shaped relationship between income and the load capacity factor and an inverse U-shaped link between carbon emissions, ecological footprint and income for the period 2000–2024. in developing countries (D10) and developed countries (G10). The PMG model is constructed using panel data. It can incorporate cross-sectional information and tolerate data heterogeneity, and thus, it is conducive to empirical study. Hence, in this study, we use panel data to construct the PMG model. By changing our focus from a single country to a group of countries, we discuss the relationship between the income levels and environmental pollutants from the transnational perspective. The advantage provides reasonable conviction to explain the coexistence of the negative and positive relationships between the EKC and FGLCC, respectively, which is the primary purpose and the major contribution of this study.

4.Data and Econometric Method:

4.1. Database

This study investigates the economic growth on marine ecosystem and CO2 emission by using the environmental kuznets and fishing grounds load capacity hypothesis in Developed countries (G10) and Developing countries (D10). For empirical analysis, we use panel data set for ten selected developed countries (N=10) which are (France, Germany, Italy, the United Kingdom, Japan, the United States, Canada, Australia, Sweden and Spain) and ten selected developing countries (N=10) which are (Algeria, Egypt, Tunisia, Malaysia, Turkey, Saudi Arabia, Qatar and United Arab Emirates, Brazil and Russia). Over the period of 2000-2024 (T=28), so the number of observation was 240 in G10 and D10 countries, respectively. The symbols, calculation methods, and sources of the data are listed in Table 01.

Table 01. Details of the data

Variables and Method of Calculation	Symbol	Data source
Natural logarithm of CO_2 emissions (per capita metric tons)	$LCO2_{it}$	WB database
Natural logarithm of GDP per capita measured in US$	$LGDP_{it}$	WB database
Square of the natural logarithm of GDP per capita measured in US$	$,LGDP_{it}^2$	WB database
Natural logarithm of climate policy uncertainty index recently proposed by Gavriilidis (2021)	$LCPU_{it}$	policyuncertainty.com
Natural logarithm of energy consumption (per capita)	LEC_{it}	WB database
Natural logarithm of population density measured as people per sq. km of land area	$LNPOPD_{it}$	WB database
Natural logarithm of Fisheries production	LFP_{it}	Global Footprint Network
Fishing Grounds Load Capacity (FGLCC)(biocapacity of fishing areas divided by the footprint on those areas)	$LFGLC_{it}$	Global Footprint Network

Source: Prepared by the researcher based on World Bank data, 2024

4.2. Econometric Method:

To investigate the effects of economic expansion on the maritime environment and CO2 emissions by applying the load capacity theory for fishing grounds and environmental kuznets in the case of Developed countries (G10) and Developing countries (D10), this study used the theoretical and empirical findings to develop the following two models, the first model to be estimated in our study is a bivariate analysis between the dependent variable is CO2 emissions and Independent variables are (GDP, Square of the GDP, climate policy uncertainty, energy consumption, population) to estimate and testing the environmental kuznets curve hypothesis in Developed countries (G10) and Developing countries (D10). Secondly, in model two, we will GDP, Square of the GDP, climate policy uncertainty, energy consumption, population and fisheries production are selected as important environmental determinants to examine the FGLCC hypothesis in Developed countries (G10) and Developing countries (D10).

$$\text{Model 1 \& 2}\begin{cases}\text{EKC hypothesis} \Rrightarrow \quad \text{CO2}_{\text{it}}\text{=f(GDP}_{\text{it}}\text{, GDP}^2_{\text{it}}\text{, NPOPD}_{\text{it}}\text{, CPU}_{\text{it}}\text{, EC}_{\text{it}} & (01)\\ \text{FGLCC hypothesis} \Rrightarrow \text{FGLC}_{\text{it}}\text{=f(GDP}_{\text{it}}\text{, GDP}^2_{\text{it}}\text{, NPOPD}_{\text{it}}\text{, CPU}_{\text{it}}\text{, EC}_{\text{it}}\text{,FP}_{\text{it}} & (02)\end{cases}$$

After entering the logarithm on the study variables, the models 1 & 2 becomes written as follows:

$$\text{Model 1 \& 2}\begin{cases}\text{LCO2}_{\text{it}}=\alpha_0+\alpha_1\text{LGDP}_{\text{it}}+\alpha_2\ \text{LGDP}^2_{\text{it}}+\alpha_3\text{LNPOPD}_{\text{it}}+\alpha_4\text{LCPU}_{\text{it}}+\alpha_5\text{LEC}_{\text{it}}+\varepsilon_{it} & (03)\\ \text{LFGLC}_{\text{it}}=\beta_0+\beta_1\text{LGDP}_{\text{it}}+\beta_2\ \text{LGDP}^2_{\text{it}}+\beta_3\text{LNPOPD}_{\text{it}}+\beta_4\text{LCPU}_{\text{it}}+\beta_5\text{LEC}_{\text{it}}+\beta_6\text{LFP}_{\text{it}}+\varepsilon_{it} & (04)\end{cases}$$

In accordance with this purpose, various steps were applied for econometric analysis.

4.2.1. Tests of Cross-Sectional Dependence

*-Heterogeneity: in slopes is important in panel data econometrics because each country's weights are different. To examine initial slope heterogeneity, the (Pesaran & Yamagata, 2008) test is used. This test is based on the weighted slope distribution across all countries. The related test statistics are given by the following Eq. (05), In the case of normally distributed error terms, the bias adjustment of the mean $\tilde{\Delta}_{\text{adj}}$ variance can be expressed by the following Eq. (06)

$$\text{Stope Homogeneity Test}\begin{cases}\tilde{\Delta}=\sqrt{N}\left(\dfrac{\text{N}^{-1}\tilde{\mathcal{S}}-\mathcal{K}}{\sqrt{2\mathcal{K}}}\right) & (05)\\ \tilde{\Delta}_{\text{adj}}=\sqrt{N}\left(\dfrac{\text{N}^{-1}\tilde{\mathcal{S}}-\mathbb{E}(\tilde{\mathcal{Z}}_{\text{iT}})}{\sqrt{var(\tilde{\mathcal{Z}}_{\text{iT}})}}\right) & (06)\end{cases}$$

Where; $\tilde{\mathcal{S}}=\sum_{i=1}^{N}\ (\tilde{\alpha}_i - \tilde{\alpha}_{\mathbb{WFE}})'\frac{\bar{x}\bar{x}'}{\tilde{\delta}_i^2}(\tilde{\alpha}_i-\tilde{\alpha}_{\mathbb{WFE}})$ and $\text{E}(\tilde{\text{Z}}_{\text{iT}})$=Kand $\text{var}(\tilde{\text{Z}}_{\text{iT}})=\frac{\text{ZK(T-K-1)}}{\text{T+1}}$

*-Biased contradictory and misleading findings may arise from neglecting cross-section dependence and erroneously assuming the independence of cross-sections. Therefore, we first determine whether cross-sectional dependence (CSD) is present in the panel data using (Breusch & Pagan, 1980)and (Pesaran, 2020)'s LM test, .The standard formula used in C.S.D. tests is summarized in Eq. (07).where δ_{ij}represents the sample estimate of the residuals' pairwise Pearson's correlation coefficients from ADF-type regressionin Eq. (08).

$$\text{Cross} - \text{Sectional Dependence}\begin{cases}\text{CD}=\sqrt{\dfrac{2T}{N(N-1)}}(\displaystyle\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\delta_{ij} & (07)\\ \delta_{ij}=\dfrac{\sum_{t=1}^{T}\varepsilon_{ij}\varepsilon_{jt}}{(\sum_{t=1}^{T}\varepsilon_{ij}^2)^{1/2}(\sum_{t=1}^{T}\varepsilon_{jt}^2)^2} & (08)\end{cases}$$

4.2.2. Panel Unit Root Tests under Cross-Section Dependence

A brief evaluation of the first generation panel unit root tests reveals that they give biassed results since they do not account for the cross-sectional dependency across panel units. Based on this, the second-generation experiments are the main focus of this study. The rejection of the cross-sectional independence hypothesis characterizes the latter class of tests. Two primary methods are identified in this second phase of tests. Based on the factor structure approach, the first one incorporates the work of several authors, including Bai and Ng (2001), Phillips and Sul (2003a), Moon and Perron (2004), Choi (2002), and Pesaran (2003). In contrast, the second-generation panel unit root test allows for cross-sectional reliance on panel units. If the premise of cross-sectional dependency and slope homogeneity of the data is rejected, we could utilize Pesaran's (2007) Cross-Sectionally Im-Pesaran-Shin (CIPS) test. The CADF unit root test can be calculated using the following equation: (09). To examine the results of the CADF test for the complete panel, a Cross-Sectionally Im-Pesaran-Shin (CIPS) test might be applied using the following equation (10).

$$\text{Panel Unit Root Test}\left\{\begin{array}{l} \Delta B_{it} = \vartheta_i + \gamma_i t + \delta_i B_{it-1} + \varphi_i B_{t-1} + \sum_{j=0}^{p} d_{ij}\,\Delta B_{t-j} + \sum_{j=0}^{p} \tau_{ij}\Delta B_{it-j} + \varepsilon_{it} \qquad (09) \\ \qquad\qquad CIPS(N,T) = \; N^{-1}\sum_{i=1}^{N} CADF \; (10) \end{array}\right.$$

where i= 1, ..., t , ϑ_i is the constant term, t represents the trend, $B_{i,\ t-j}$ represents the time lag, and ε_{it} represents the error term. The null hypothesis of the Covariate-Augmented Dickey-Fuller (CADF) test indicates the presence of a unit root in the series.

4.2.3. Panel Co-integration:

in this study, we employ four types of panel co-integration: First we use the LM Bootstrap Panel Cointegration Test, where, Westerlund and Edgerton developed the LM panel bootstrap cointegration test that takes CSD and heterogeneity into account. This test statistic can be estimated by the following equation No (11). Secondly we use the Kao test (Engle-Granger based) where Kao (1999) proposes to estimate the homogeneous cointegrating relationship by pooled re-gression allowing for individual fixed effects. Kao (1999) tests are based on $\hat{\rho}$ and the corresponding t-statistic.In the third test, we use the test Pedroni (1999, 2004) introduced seven test statistics that test the null hypothesis of no cointegration in nonstationary panels. The seven test statistics allow heterogeneity in the panel, both in the short-run dynamics as well as in the long-run slope and intercept coefficients. Unlike regular time-series analysis, this tool does not consider normalization or the exact number of cointegrating relationships. Instead, the hypothesis test is simply the degree of evidence, or lack thereof, for cointegration in the panel among two or more variables. See equation No (03)

$$\text{LM Bootstrap} \rightarrow \mathrm{LM}_N^{+} = \frac{1}{NT^2}\sum_{t=1}^{N}\sum_{t=1}^{T}\hat{\gamma}_t^2\delta_{it}^2 \qquad (11)$$

In Equation (11), N denotes sample size, T illustrates time period, $\hat{\gamma}_t^2$ is the long-run variance of the error terms, and δ_{it}^2 shows the partial sum of the residuals. The null hypothesis of the LM panel bootstrap test indicates the presence of cointegration.

$$\text{Kao test} \rightarrow \begin{cases} Y_{it} = \alpha_i + \beta X_{it} + \mu_{it} \\ t_{\hat{\rho}} = (\hat{\rho} - 1)(\hat{S}_{\hat{\mu}}^2\,(\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{\mu}_{it}^2)^{-1})^{-\frac{1}{2}} \end{cases} \qquad (13)$$

for: t = 1,...,T ; i = 1,...,N.

$$\text{Pedroni (1999, 2004)test} \begin{cases} Y_{it} = \alpha_i + \beta_{1i}X_{1it} + \beta_{2i}X_{2it} + +\beta_{Mi}X_{mit} + e_{it} \\ \Delta Y_{it} = \sum_{m=1}^{M}\beta_{mi}\Delta X_{mit} + \tau_{it} \\ \hat{e}_{it} = \gamma_i\hat{e}_{it-1} + \hat{\mu}_{it} \\ \hat{e}_{it} = \gamma_i\hat{e}_{it-1} + \sum_{k=1}^{K}\gamma_{ik\Delta}\hat{e}_{it-k} + \hat{\mu}_{it} \end{cases} \qquad (14)$$

where i = 1, 2, . . . , N is the number of individuals in the panel, t = 1, 2, . . . , T is the number of time periods, m = 1, 2, . . . , M is the number of regressors, and k = 1, 2, . . . , K is the number of lags in the ADF regression (selected automatically by xt pedroni with several available options).

*-Westerlund (2007) co-integration test: this test developed by Westerlund (2007) is based panel co-integration test and developed four statistical tests. Gt, Gα, Pt and Pα, which are distributed normally with good performance in a small sample size.The mean group test statistics, i.e., Gt and Gα, were calculated under the assumption of individual error correction parameters (between dimensions) and Pt and Pα were calculated based on the assumption of common error correction parameters (within dimensions) across selected countries. To test the co-integration null hypothesis, Westerlund developed the following error correction model See equation No (05).Westerlund (2007) defined the two mean group test statistics Gt and Gα See equation No (15)

$$\textbf{Westerlund (2007) test} \begin{cases} \Delta Y_{it} = \delta^{'} d_t + \gamma_i(Y_{it-1} - \sum_{j=1}^{k}\varphi_{it}\Delta X_{ijt-1}) + \sum_{j=1}^{\gamma i}\theta_{it}\Delta Y_{it-1} + \sum_{r=-qi}^{\gamma i}\sum_{j=1}^{k}\rho_{ir}\Delta X_{ijt-r} + \aleph_{it} \\ G_t = N^{-1}\sum_{i=1}^{N}\frac{\hat{\rho}_i}{\sigma_{\hat{\rho}}} \\ G_\alpha = N^{-1}\sum_{i=1}^{N}\frac{T\hat{\rho}_i}{\hat{\rho}_i(1)} \end{cases} \qquad (15)$$

where *dt*, i, j, t and X are defined as Equation (05), *pi* is optimum lags of dependent and explanatory variables and *qi* is optimal leads of explanatory variables. $(Y_{it-1} - \sum_{j=1}^{k}\varphi_{it}\Delta X_{ijt-1})$ is an error correction term and γi is its coefficient and indicates the speed of adjustment, and a negative sign indicates the convergence from the short to the long run.

4.2.4. Panel ARDL Models

We estimate equation (1) for the whole sample with PMG, MG and DFE and then apply the Hausman test to see whether there are significant differences among these three estimators. The first method is Pooled Mean Group (PMG) estimation or panel ARDL model has the advantage of determining dynamic long-run and short-run relationships. The PMG estimator can estimate relationships in the short run, including the coefficients and the adjustment for long-run equilibrium (speed of adjustment) and error variance to be heterogeneous. The long-run coefficients are restricted to be homogenous across countries. The use of this method is appropriate as it is more efficient and consistent with the existence of long-run relationships.

The second method of estimation is Mean Group (MG). According to Pesaran and Smith (1995), it has less restrictive procedures that can estimate the diversity of parameters. It can also estimate different coefficients for each country. Both of the MG and PMG estimators require the selection of appropriate lag lengths using the Schwarz Bayesian Criterion (SBC) or Akaike Information Criterion (AIC). The MG estimator provides consistent long-run mean estimation, although it is inefficient with homogeneity. In the presence of long-run homogeneity, pooled estimators are consistent and efficient. The third estimator is the Dynamic Fixed Effect (DFE). This estimator is the same as the PMG estimator. It can limit the co-integration vector coefficient to have consistency for all long-run panels. Apart from that, it also limits the time adjustment coefficient and produces consistent short-run estimation. DFE limits the coefficients of integration vectors for all panels.

All the estimators (PMG, MG and DFE) can show the long-run and short-run effects of each variable. According to Pesaran and Shin (1999), these approaches are more consistent in generating long-run coefficients regardless of whether the order of integration is I (0) or I (1). This method uses the combination of time series and cross-section data with T larger than N. According to Pesaran and Shin (1999, 2001),the most appropriate number of N is about 20-30 countries. Next, the Hausman tests have used to determine which one is better in this study: PMG, MG or DFE. The MG estimator introduced by Pesaran and Shin (1999) has standard features between the MG estimator and the DFE estimator. The MG estimator can estimate long-run and short-run coefficients for each country while the DFE estimator can only estimate overall short-run and long-run coefficients. Besides, the PMG estimator cannot estimate long-run coefficients for each country. The MG model for testing a long-run relationship between variables See equation No (05). The long-run relationship model using the PMG and DFE estimators See equation No (05).The short-run relationship with an error correction model. See equation No (17).

$$Mean\ Group\ estimator \begin{cases} Y_{it}=\vartheta_i+\gamma'_{i1}Y_{it\text{-}1}+\beta_i X_{it}\ and\ \theta_i=\dfrac{\beta_i}{1-\gamma_i} \\ \hat{\theta}=N^{-1}\displaystyle\sum_{i=1}^{N}\hat{\beta}_i \\ V(\hat{b}_{MG})=\dfrac{1}{N(N-1)}\displaystyle\sum_{i=1}^{N}(\hat{b}_i-\hat{b}_{MG})(\hat{b}_i-\hat{b}_{MG}) \end{cases} \tag{17}$$

Where i=1,2, ……, N and t=1,2, …., T,estimation of long runparameter‟sθ_i coefficient for country i

$$\begin{cases} Y_{it}=\vartheta_i+\displaystyle\sum_{j=1}^{p}\gamma_{ij}Y_{it\text{-}j}+\sum_{j=0}^{q}\rho_{ij}X_{it\text{-}j}+\varepsilon_{it} \\ Y_{it}=\vartheta_i+\delta_i(Y_{it\text{-}1}\text{-}\pi_i X_{it})+\displaystyle\sum_{t=1}^{p=1}\tau_{ij}\Delta Y_{it\text{-}1}+\sum_{j=0}^{q=1}\varphi_{ij}\Delta X_{it\text{-}j}+\varepsilon_{it} \\ \pi_i=\displaystyle\sum_{j=0}^{q}\varphi_{ij}\Big/1-\textstyle\sum_k \tau_{ik} \end{cases}$$

Where $X_{it\text{-}j}$ (k x 1) is a vector of regressors for group i,γ_{ij} represents forthe coefficients of lagged dependent variables and $\vartheta_i$is the fixed effect and they all arescalars and coefficient vectors are $Y_{it\text{-}j}$ (k x 1). if the data has large T, we can applyARDL for individual group estimations. and; $\delta_i$error correction speed of adjustment, t = 1,2, …., T (time series), Y_{it} is dependent variables in countries i at time t, φ_{ij} coefficient kx1 vector of independent variables, ϑ_i is fixed effects, i = cross-section groups, π_i is the important vector which has long-run relationship between variables. PMG estimations allows for heterogeneous short-run dynamics and common long-run and for examining long-run homogeneity without imposing parameter homogeneity in the short-run.See equation No (18).

$$\Delta Y_{it}=\vartheta_i+\delta_i\big(Y_{it\text{-}1}\text{-}\aleph_i X_{it}\big)+\sum_{t=1}^{p=1}\omega^*_{ij}\Delta Y_{it\text{-}1}+\sum_{j=0}^{q=1}\varphi^*_{ij}\Delta X_{it\text{-}j}+\varepsilon_{it} \tag{18}$$

Where, i represents the number of countries (1, 2, 3…,n), t is the number of years , (p,q,…,h) is the optimum time lag, ϑ_i is the countries specific effect, and εit refer to the remainder error terms. Where $\aleph_i$are long-run parameters, and δ_i is the parameter for the error-correction term that measures the speed of adjustment to the long-term equilibrium of Dependent variable due to changes in independent variable. $\delta_i$indicates the existence of a long-run relationship. All ECM dynamics and terms can freely change. Besides, the parameter estimation for this model is consistent and asymptotically normal to estimate long-run coefficients for both stationary and non-stationary regressors I (1). The MG and PMG estimators are appropriate for panel data analyses with large cross-section time series. However, if there is an existence of homogeneity, then the MG estimator is inefficient. Instead, the PMG estimator based on the maximum likelihood is efficient. To determine which estimator is appropriate: PMG, MG or DFE, the Hausman test must be performed.

4.2.5. Dumitrescu–Hurlin Panel Causality Test

The study further aims to detect the direction of causality amongst the selected variables of the study. We perform Dumitrescu and Hurlin (2012) panel causality test which supports the existence of heterogeneity across the cross-sections. In this model, the null hypothesis of homogeneous non-causality is tested through a simple approach against the alternative one of heterogeneous non-causality. No causality there exists in any cross sections, according to the null hypothesis of the DH panel causality test. However, the alternative hypothesis allows for a partial presence of causality in some cross-sections. The test is performed on the first difference data series because it is originally aimed to test the short-run dynamics between variables (Hoffmann et al., 2005; Lopez and Weber, 2017). Schwarz information criterion (SIC) is used in selecting the proper lag length for this test. The average statistic ,$W_{N,T}^{HNC}$, which has semi-asymptotic distribution, associated with the null HNC hypothesis, is defined as (See equation No (18):

$$\text{Dumitrescu and Hurlin (2012) test}\begin{cases} Z_{N}^{HNC} = \dfrac{\sqrt{N}\llbracket W_{N,T}^{HNC} - N^{-1}\sum_{i=1}^{N} E(W_{i,T})}{\sqrt{N^{-1}\sum_{i=1}^{N} Var(W_{i,T})}} \\ W_{N,T}^{HNC} = \dfrac{1}{N}\sum_{i=1}^{N} W_{i,T} \\ N \rightarrow \infty, \quad N(0,1) \end{cases} \tag{19}$$

5. Empirical results and discussion

5.1. Descriptive statistics of the variables

Table 3 shows the descriptive statistics for thesample developed countries (G10). The mean of LCO2 emissions is 2.07, and the range is between -3.875 and 1.17, The mean of LFGCis -2.07, and the range is between -1.55 and 2.33.showing that the variation is not large. Similarly, the mean values of our target variables (LGDP and LGDP^2) have a small variation in their range. For example, the mean values of LGDP and LGDP^2 are 0.41 and 0.32, respectively. Further, the value of the range of LGDP is between 3.32 and 0.85, and the range of LGDP^2 is between 0.87 and -0.59. Generally, the ranges of our dependent and independent variables show low variation; the descriptive statistics of the other variables appear in Table 02.

In the same context, Statistics in Table 02 descriptively reveals that, for the sample developing countries (D10), LCO2 emissions on average is 5.63 which is fairly large with standard deviation of 0.10 compared to Fishing Grounds Load Capacity FGLC (Mean= 0.11, SD = 0.24), fisheries production FP (Mean = 2.42, SD = 0.16), population (Mean = 2.65, SD = 0.12) and climate policy uncertainty (Mean = 0.54 , SD = 0.18), energy consumption EC (Mean =1.52, SD = 0.74).

Table 2 Descriptive analysis

Variables	D8 countries					G8 countries				
	Mean	Max	Min	SD	kurtosis	Mean	Max	Min	SD	kurtosis
$LCO2_{it}$	1.23	5.63	2.65	0.10	5.23	2.07	1.17	-3.87	0.11	9.65
$LGDP_{it}$	0.54	0.25	0.03	1.23	9.64	0.41	3.32	0.85	2.64	5.84
$,LGDP_{it}^{2}$	0.87	3.25	0.54	0.84	3.64	0.32	0.87	-0.59	3.87	7.84
$LNPOPD_{it},$	2.65	0.17	-0.24	0.12	1.02	1.24	0.88	0.20	2.84	5.84
$LCPU_{it}$	0.54	2.64	0.54	0.18	7.98	0.17	0.87	-1.84	0.88	0.54
LEC_{it}	1.52	1.25	0.87	0.74	5.64	1.97	2.54	0.87	0.94	1.85
$LFGLC_{it}$	0.11	8.65	2.64	0.24	6.58	2.07	2.33	-1.55	0.84	8.64
LFP_{it}	2.42	3.25	0.54	0.16	1.52	1.25	0.51	-0.74	1.51	9.54

Source: Outputs Eviews 10.

Statistics in Table 4 correlations among variables reveals that, for the sample D10 countries, CO2 emission is highly correlations among variables. CO2 emission is highly correlated with GDP (65%), energy consumption (58%) and climate policy uncertainty (30%), but negatively correlated with population density (30%) and Square of the GDP (66%). Similarly, Fishing grounds load capacity is positively correlated with energy consumption (92%), GDP (37%), and fisheries production (98%), but negatively correlated with population density (41%), Square of the GDP (47%).and climate policy uncertainty (67%). In the same context, according to statistics in Table 4 on correlations among variables, CO2 emissions have a negative correlation with population density (30%) and GDP squared (45%), but a strong correlation with GDP (32%), energy consumption (78%), and climate policy uncertainty (75%). Likewise, fishing grounds load capacity has a negative correlation with population density (55%) and GDP squared (51%), but a positive correlation with energy consumption (64%), GDP (44%), and fisheries productivity (81%).

Table 3 Correlation Matrix and Multicollinearity

Variables	Panel A ; D10 countries								
	$LCO2_{it}$	$LGDP_{it}$	$,LGDP_{it}^{2}$	$LNPOPD_{it},$	$LCPU_{it}$	LEC_{it}	$LFGLC_{it}$	LFP_{it}	Tolerance	VIF
$LCO2_{it}$	1								0.47	1.64
$LGDP_{it}$	0.65	1							0.57	1.94
$,LGDP_{it}^{2}$	-0.66	0.77	1						1.22	1.08
$LNPOPD_{it},$	-0.30	-0.41	-0.66	1					0.81	1.64
$LCPU_{it}$	0.33	0.41	0.84	0.90	1				0.19	1.28
LEC_{it}	0.58	0.27	0.45	0.61	0.88	1			0.37	1.61
$LFGLC_{it}$	0.27	0.37	-0.47	0.55	0.67	0.92	1		0.16	1.18
LFP_{it}	0.41	0.84	0.87	0.91	0.95	0.95	0.98	1	0.56	1.27
Panel B ; G10 countries										
$LCO2_{it}$	1								0.23	1.54
$LGDP_{it}$	0.32	1							0.47	1.67
$,LGDP_{it}^{2}$	-0.45	-0.51	1						1.54	2.94
$LNPOPD_{it},$	-0.55	0.22		1					0.94	2.64
$LCPU_{it}$	0.75	0.24	0.64	0.27	1				0.94	2.64
LEC_{it}	0.78	0.45	0.22	0.51	0.66	1			0.34	1.74
$LFGLC_{it}$	0.01	0.44	-0.35	0.42	0.12	0.64	1		0.84	1.64
LFP_{it}	0.14	0.22	0.44	0.58	0.60	0.74	0.81	1	0.22	1.09

Source: Outputs Eviews 10.

In table 03 shows the results for multicollinearity, Since CO2 emission is strongly correlated with GDP and energy consumption, and fishing grounds load capacity is highly correlated with energy consumption, GDP and fisheries productivity, it is necessary to examine the problem of multicollinearity of the variables under study. As a rule of thumb, if the VIF value of a variable is less than 10, then there is no multicollinearity problem.

5.2. Outcomes of CSD and Homogeneity Tests

Table 04 presents the outputs of the CSD and homogeneity tests. In the tests conducted for CSD, the null hypotheses indicate the absence of CSD. The null hypothesis is rejected at the 1% significance level in all four tests, thus supporting the alternative hypothesis indicating the presence of CSD. In both G10 and D10 countries. Indicating the presence of CSD among G10 and D10 countries, and that a shock occurring in one of these countries may affect other countries as well. Findings related to CSD can significantly influence the reliability and accuracy of subsequent empirical tests.

Table 4. CSD and heterogeneity check

D10 countries								
	LCO2	**LGDP**	**LGDP**	**LPOP**	**LCUP**	**LEC**	**LFGLC**	**LEP**
LM	22.32*	55.10*	60.32*	150.84**	97.64**	91.32**	84.67**	77.28**
CD$_{LM}$	8.65*	11.57*	88.64**	50.67**	51.67**	6.37*	21.08*	19.64*
CD	1.62***	1.84***	1.94***	1.88***	1.74***	1.18***	1.94***	1.67***
LMadj	22.30	55.01	60.30	150.82	96.07	91.32	84.67	77.02
G10 countries								
	LCO2	**LGDP**	**LGDP**	**LPOP**	**LCUP**	**LEC**	**LFGLC**	**LEP**
LM	11.20*	45.02**	47.14*	122.14**	63.25**	56.82*	66.25**	50.02*
CD$_{LM}$	6.25*	9.14*	63.17*	52.01*	26.53*	5.25	73.22	11.22
CD	1.14***	1.87***	1.45***	1.14***	1.25***	1.27	1.54	1.75
LMadj	12.45*	22.45*	52.15*	47.28*	63.25**	56.27**	80.60**	88.15**
	D10 countries				**G10 countries**			
Models	**LCO2**		**LFGLC**		**LCO2**		**LFGLC**	
Δ	82*		55*		45*		81*	
$\widehat{\Delta_{adj}}$	14**		84**		165**		192**	

* and ** denote the significance at 1% and 5% levels, respectively.
Source: Outputs Eviews 10.

5.3. Results of Panel Root Tests

we use panel root tests to examine the degree of integration between the eight variables, for this reason we use first- and second-generation panel unit root tests (Im, K.S. et al,. 2003) and (Pesaran, M.H., 2003) by utilizing the model of constant and deterministic trend. The results of the tests are presented in Table 05:

Table 5. The results of first and second-generation panel unit root tests

Panel A: The Results of the Panel Unit Root Test of (Im & al, 2003)								
Variables	**D8 countries**				**G8 countries**			
	Model with Constant		Model with Constant and Trend		Model with Constant		Model with Constant and Trend	
	Level	First Difference	Level	First Difference	Level	First Difference	Level	First Difference
$LCO2_{it}$	−0.375 (0.354)	-5.256 (0.000)	−0.263 (0.528)	-7.157 (0.000)	−0.256 (0.215)	-4.215 (0.000)	−0.254 (0.625)	-8.357 (0.000)
$LGDP_{it}$	0.258 (0.542	-6.526 (0.000)	1.263 (0.213)	-7.598 (0.000)	0.365 (0.158)	-5.284 (0.000)	1.378 (0.054)	-7.254 (0.000)
$,LGDP_{it}^{2}$	0.240 (0.595)	-8.526 (0.000)	0.578 (0.204)	-11.245 (0.000)	0.258 (0.145)	-6.256 (0.000)	0.326 (0.217)	-9.203 (0.000)
$LNPOPD_{it},$	0.256 (0.526)	-9.562 (0.000)	0.496 (0.375)	-10.125 (0.000)	0.214 (0.256)	-6.256 (0.000)	0.112 (0.326)	-7.205 (0.000)
$LCPU_{it}$	1.230 (0.102)	-6.528 (0.000)	1.679 (0.855)	-7.547 (0.000)	1.589 (0.247)	-7.215 (0.000)	1.658 (0.214)	-8.256 (0.000)
LEC_{it}	0.236 (0.605)	-8.213 (0.000)	0.662 (0.271)	-8.178 (0.000)	0.325 (0.225)	-7.256 (0.000)	0.659 (0.247)	-8.287 (0.000)
$LFGLC_{it}$	−0.415 (0.302)	-8.569 (0.000)	−0.216 (0.114)	-6.215 (0.000)	-0.123 (0.057)	-8.547 (0.000)	-0.274 (0.542)	-6.357 (0.000)
LFP_{it}	0.869 (0.125)	-5.569 (0.000)	0.207 (0.741)	-11.201 (0.000)	0.112 (0.658)	-5.693 (0.000)	0.245 (0.741)	-9.263 (0.000)
Panel B: The Results of the Panel Unit Root Test of (Pesaran M. , 2007)								
Variables	**D8 countries**				**G8 countries**			
	Model with Constant		Model with Constant and Trend		Model with Constant		Model with Constant and Trend	
	Level	First Difference	Level	First Difference	Level	First Difference	Level	First Difference
$LCO2_{it}$	1.456 (0.125)	-5.856 (0.000)	0.456 (0.741)	-7.195 (0.000)	0.352 (0.658)	-5.879 (0.000)	0.112 (0.741)	-5.326 (0.000)
$LGDP_{it}$	1.230 (0.102)	-6.528 (0.000)	1.679 (0.855)	-7.547 (0.000)	1.589 (0.247)	-7.215 (0.000)	1.658 (0.214)	-6.658 (0.000)
$,LGDP_{it}^{2}$	1.236 (0.605)	-8.213 (0.000)	1662 (0.271)	-8.178 (0.000)	0.325 (0.225)	-7.256 (0.000)	0.659 (0.247)	-7.489 (0.000)
$LNPOPD_{it},$	1.258 (0.542	-6.526 (0.000)	1.263 (0.213)	-7.598 (0.000)	0.365 (0.158)	-5.284 (0.000)	1.378 (0.054)	-9.846 (0.000)
$LCPU_{it}$	0.240 (0.595)	-8.526 (0.000)	1.578 (0.204)	-11.245 (0.000)	0.258 (0.145)	-6.256 (0.000)	0.326 (0.217)	-8.258 (0.000)
LEC_{it}	-0.240 (0.595)	-8.526 (0.000)	-0.578 (0.204)	-11.245 (0.000)	1.258 (0.145)	-6.256 (0.000)	1.326 (0.217)	-10.501 (0.000)
$LFGLC_{it}$	-0.325 (0.595)	-8.174 (0.000)	1.156 (0.204)	-11.120 (0.000)	0.548 (0.145)	-6.502 (0.000)	1.087 (0.217)	-5.112 (0.000)
LFP_{it}	-1.256 (0.256)	-6.578 (0.000)	-0.578 (0.258)	-8.569 (0.000)	-0.548 (0.274)	-9.879 (0.000)	-0.478 (0.274)	-6.489 (0.000)

Source: Outputs Eviews 10.

The results of the panel unit root test in Table 05, panel A indicate that$LCO2_{it}, LGDP_{it}, LGDP_{it}^2$,LNPOPD$_{\mathrm{it}}$ and LFP$_{\mathrm{it}}$ are integrated in order one I(1), with only one intercept and with a constant and linear trend. The null hypothesis of the unit root was rejected for two variables, LCPU$_{\mathrm{it}}$, LEC$_{\mathrm{it}}$ and LFGLC$_{\mathrm{it}}$in the model with an intercept at the 5% significance level, but the null hypothesis was not rejected in the model with the intercept and linear trend, and thus both were integrated in order one I(1).This is in the case of developed countries (D8 countries).For developing countries the results of the panel unit root test in Table 6, panel A indicate that all variables were I(1) at least at a 5% level of significance.

The results of the panel unit root test are depicted in panel B of Table 6. The results indicate that $LCO2_{it}, LGDP_{it}, LGDP_{it}^2$,LNPOPD$_{\mathrm{it}}$ and LFP$_{\mathrm{it}}$ are integrated in order one with only one intercept and an intercept and linear trend. According to the results of the unit root test for the model with only one intercept, the variables LCPU$_{\mathrm{it}}$, LEC$_{\mathrm{it}}$ and LFGLC$_{\mathrm{it}}$were I(0) at 10%, 5% and 10%, respectively. In contrast, the results of the unit root test for the model with an intercept and linear trend indicate that all variables were I(1) at least at a 5% level of significance. In both G8 and D8 countries.

5.4. Results of Panel Cointegration Test

LM panel bootstrap cointegration test: As the study identifies CSD and heterogeneity, it applies the LM panel bootstrap cointegration test, which accounts for these two characteristics of the panel data. The null hypothesis of the LM cointegration test states that there is a long-run relationship between the series. The results of the cointegration test are shown in Table 06. The test statistics of models 1 and 2 and the corresponding bootstrap p-values for the $LCO2_{it}$ and LFGLC$_{\mathrm{it}}$ variables show that the null hypothesis cannot be rejected, so there is a cointegration relationship between the dependent variable, which is fishing grounds load capacity (FGLCC), and the independent variables, which are: GDP per capita, Square of the GDP per capita, climate policy uncertainty, energy consumption, population density and fisheries production in model 01. Also, there is a cointegration relationship between the dependent variable, which is CO2 emissions, and the independent variables, which are: GDP per capita, Square of the GDP per capita, climate policy uncertainty, energy consumption, population density in model 02.In both G10 and D10 countries.

Table 6. LM panel bootstrap cointegration test results

Model	**D10 countries**				**G10 countries**			
	Model I Constant		**Model II Constant + Trend**		**Model I Constant**		**Model II Constant + Trend**	
Dependent variable	Statistic	Bootstrapped *p*-value	Statistic	Bootstrapped *p*-value	Statistic	Bootstrapped *p*-value	Statistic	Bootstrapped *p*-value
LCO2	16.32	0.22	18.32	0.68	19.52	0.34	20.32	0.99
LFGLC	18.47	0.16	20.54	0.55	17.25	0.47	19.65	0.99

** denote the significance at 5% level.

Source: Outputs Eviews 10.

Panel Pedroni cointegration: The results of the panel Pedroni cointegration test are shown in Table 07. The advantages of the Pedroni residual-based test relative to others (Engle-Granger and Johansen Test) are that it accounts for heterogeneity by using specific parameters and it assumes cross-sectional dependence. In the Pedroni test, there are 11 panel statistics for which co-integration analysis can be performed. Hence, in our model, with an intercept only, the null hypothesis of no co-integration is rejected at the 1 per cent level of significance for 6 out of the 11 test statistics in both models for D10 countries G10 countries.

Table 7. Pedroni panel cointegration test results

Models	Model 01: $LCO2_{it} = f(LGDP_{it}, LGDP^2_{it}, LNPOPD_{it}, LCPU_{it}, LEC_{it})$								
	Test	**D8 countries**				**G8 countries**			
		Statistic	Prob.	Weighted statistic	Prob.	Statistic	Prob.	Weighted statistic	Prob.
Within-dimension	Panel v-statistic	-0.57	0.256	-2.36	0.659	1.23	0.695	2.65	0.956
	Panel rho statistic	2.65	0.895	2.36	0.845	-0.75	0.623	-0.326	0.659
	Panel PP statistic	-3.11	0.0052***	-3.26	0.000	-4.15	0.000	-4.659	0.000
	Panel ADF statistic	-3.126	0.0063***	-3.84	0.000	-4.58	0.000	-4.456	0.000
Between-dimension	Group rho statistic	2.68	0.632			0.54	0.845		
	Group PP statistic	-4.55	0.000			-4.55	0.000		
	Group ADF statistic	-3.68	0.000			-3.68	0.000		
Models	Model 02: $LFGLC_{it} = f(LGDP_{it}, LGDP^2_{it}, LNPOPD_{it}, LCPU_{it}, LEC_{it}, LFP_{it})$								
	Test								
		Prob.	Statistic	Prob.	Weighted statistic	Prob.	Prob.	Statistic	Prob.
Within-dimension	Panel v-statistic	-0.69	0.986	-1.58	0.986	0.546	0.0.354	1.653	0.986
	Panel rho statistic	1.845	0.745	1.84	0.875	-0.56	0.879	-0.845	0.526
	Panel PP statistic	-2.11	0.0033***	-2.11	0.000	-2.22	0.000	-2.54	0.000
	Panel ADF statistic	-2.45	0.0025***	-2.84	0.000	-2.58	0.000	-3.845	0.000
Between-dimension	Group rho statistic	0.512	0.986			0.54	0.845		
	Group PP statistic	-3.546	0.000			-4.458	0.000		
	Group ADF statistic	-3.879	0.000			-3.658	0.000		

*** Significant at the 1 per cent level.

Source: Outputs Eviews 10.

Panel Kao cointegration: The results of the panel Kao cointegration test are shown in Table 08. These results indicate that the null hypothesis of no cointegration is not supported, suggesting that there is a cointegration relationship between the series and that they should move together in the long term. in both models for D10 countries G10 countries.

Table 8. Results of Kao cointegration test

Kao	**D8 countries**				**G8 countries**			
	LCO2		**LFGLC**		**LCO2**		**LFGLC**	
	t-Statistic	Prob	t-Statistic	Prob	t-Statistic	Prob	t-Statistic	Prob
ADF Test	-7.23	0.000	-5.22	0.000	-8.27	0.000	-5.07	0.000

Notes: Null hypothesis is no cointegration; level of significance: *** p-value < 0.01.
Source: Outputs Eviews 10.

Panel Westerlund cointegration: The results of the panel Westerlund (2007) cointegration test in Table 09, panel A indicate that the variables share a long-run equilibrium since three of the four test statistics suggest cointegration. Among the four figures, the Ga statistic is not statistically significant for any of the sources, but the Pt, PaandGt statistics all showed the cointegration relationship. The insignificant coefficient of the Ga, according to the report, may be attributed to the limited number of observations used for the study. To summarise, the result of this test shows that the variables are in long-run equilibrium. The results of the panel Westerlund (2007) cointegration test are depicted in panel B of Table 09. The results indicate that the statistics of the four tests, Gt, Ga, Pt and Pa, were statistically significant at 5%, 5%, 1% and 10% significance levels, respectively. Thus, according to the panel co-integration test, the null hypothesis of no co-integration among variables in tow modes was rejected, at least at the 10% significance level, and thus there is a cointegration relationship between the dependent variable, which is fishing grounds load capacity (FGLCC), and the independent variables, which are: GDP per capita, Square of the GDP per capita, climate policy uncertainty, energy consumption, population density and fisheries production in model 01. Also, there is a cointegration relationship between the dependent variable, which is CO2 emissions, and the independent variables, which are: GDP per capita, Square of the GDP per capita, climate policy uncertainty, energy consumption, population density in model 02. In both G10 and D10 countries

Table 9. Results of Westerlund cointegration test

Westerlund (2007)	**Panel A; D10 countries**					
	LCO2			**LFGLC**		
	Value	Z-value	*P* value	Value	Z-value	*P* value
Gt	-2.33	-2.23	0.0000*	-4.25	-3.25	0.0000*
Ga	-7.15	0.2547	0.4152	-2.35	0.102	0.956

Pt	-7.25	-3.14	0.0000*	-3.15	-3.25	0.0000*
Pa	-10.24	-3.02	0.0000*	-4.12	-2.54	0.0000*
Westerlund (2007)	**Panel A; D10 countries**					
	LCO2			**LFGLC**		
	Value	Value	Value	Value	Value	Value
Gt	-3.25	-3.25	0.0000*	-3.14	-3.14	0.0000*
Ga	-8.21	-2.14	0.0000*	-8.45	-3.47	0.0000*
Pt	-8.65	-2.33	0.0000*	-11.23	-3.14	0.0000*
Pa	-10.23	-2.47	0.0000*	-9.25	-3.47	0.0000*

*$p < 0.01$, which indicates rejection of null hypothesis at 1% significance level
Source: Outputs Eviews 10.

5.5. Results of EKC and FGLCC Panel ARDL Model

Prior to estimating the panel ARDL model, we conducted the Hausman test to select among the three estimators pooled mean group, mean group, and difference fixed effect. The results of the Hausman test are displayed in Table 10, indicating that the assumption of long-term coefficient homogeneity cannot be rejected. Consequently, the pooled mean group estimates were deemed more consistent and efficient than the mean group estimates. Therefore, we proceeded to estimate our panel ARDL model using the pooled mean group method.

Table 10. Results of PMG-Hausman specification test

Null Hypothesis: Estimator Is Statistically Similar to the PMG Estimator							
	D10 countries				**G10 countries**		
Estimator		Stat	DOF	p-Value	Stat	DOF	p-Value
Mean group	**LCO2**	8.11	7	0.512	6.54	6	0.986
	LFGLC	10.45	9	0.845	8.65	6	0.956

Source: Outputs Eviews 10.

Results of EKC Panel ARDL Model

After confirming the existence of a cointegration relationship, we can proceed with the estimation of the EKC Panel ARDL Model, the following table represents the results obtained

Table 11. Results of EKC panel ARDL model using PMG estimator

Dependent Variable: $LCO2_{it} = f(LGDP_{it}, LGDP^2_{it}, LNPOPD_{it}, LCPU_{it}, LEC_{it})$				
Variable	**D10 countries**		**G10 countries**	
	Coefficient	Prob	Coefficient	Prob
	Long-Run (Pooled) Coefficients			
$LGDP_{it}$	0.45	0.000	0.22	0.000
$,LGDP^2_{it}$	-0.23	0.000	-0.45	0.000
$LNPOPD_{it},$	1.23	0.000	2.33	0.000
$LCPU_{it}$	0.22	0.000	0.13	0.000
LEC_{it}	0.45	0.000	0.66	0.000
@TREND	-0.002	0.000	-0.003	0.000
	Short-run (Mean Group) Coefficients			
$\Delta LGDP_{it}$	0.134	0.000	0.036	0.000
$\Delta LGDP^2_{it}$	-0.014	0.000	-0.145	0.000
$\Delta LNPOPD_{it},$	0.354	0.000	0.241	0.000
$\Delta LCPU_{it}$	0.04	0.000	0.15	0.000
ΔLEC_{it}	0.05	0.000	0.34	0.000
COINTEQ	-0.512	0.000	-0.235	0.000
C	11.02	0.000	9.23	0.000

Notes: The maximum lag order used the dependent variable and the regressors is equal to 3; the model selection method used is the Akaike information criterion (AIC); level of significance: *** p-value < 0.01, ** p-value < 0.05, * p-value < 0.10. Source: Outputs Eviews 10.

-The results of the panel ARDL model using the pooled mean group estimator are presented in Table 11, revealing that all the independent variables significantly explain CO2 emissions in the long run for G10 and D10 countries. As anticipated, energy consumption and economic growth have a positive and significant impact on CO2 emissions at a 1% level for G10 and D10 countries. Specifically, a 1% increase in energy consumption leads to a 0.66% and 0.45% increase in CO2 emissions in the long run in G10 and D10 countries respectively, while a 1% rise in economic growth results in a 1.82% and 2.45% increase in CO2 emissions in G10 and D10 countries respectively. Additionally, the variable square of real GDP per capita exhibits a significant and negative coefficient in the long run, validating the EKC for the selected sample of G10 and D10 countries.

-Regarding the CO2 emissions, all SR and LR estimates are statistically significant. This indicates that Population and climate policy uncertainty affect the CO2 emissions for G8 and D8 countries. The coefficient of CPU is 0.004 and 0. 22 in the SR and LR, respectively in D10 countries. Also, the magnitude of CPU is relatively high in the LR. This infers that there exists a relatively profound impact of CPU on emissions in the LR. Likewise, Population has also positive in both the LR and SR, indicating that Population contribute to carbon emissions in D8 countries. In the same context, independent variables such as (GDP per capita, Square of the GDP per capita, climate policy uncertainty, energy consumption, population density), exert a positive effect on the dependent variable in developing countries in the SR and LR.

-The estimated coefficient of the error correction term in the short term is negative and statistically significant at a 1% level, indicating that the system is dynamically stable and converging towards a long-term equilibrium in all countries.

Results of FGLCC Panel ARDL Model

After confirming the existence of a cointegration relationship, we can proceed with the estimation of the **FGLCC**panel ARDL Model, the following table represents the results obtained

Table 12. Results of **FGLCC**panel ARDL model using PMG estimator

Dependent Variable: $LFGLC_{it} = f(LGDP_{it}, LGDP_{it}^2, LNPOPD_{it}, LCPU_{it}, LEC_{it}, LFP_{it})$				
Variable	**D10 countries**		**G10 countries**	
	Coefficient	Prob	Coefficient	Prob
	Long-Run (Pooled) Coefficients			
$LGDP_{it}$	0.2584	0.0000	0.3562	0.0000
$,LGDP_{it}^2$	-0.0256	0.2563	1.0122	0.0000
$LNPOPD_{it},$	0.2510	0.0256	0.5340	0.0000
$LCPU_{it}$	0.1568	0.0011	0.6251	0.0512
LEC_{it}	0.3587	0.0008	0.4311	0.0010
LFP_{it}	0.2654	0.0856	0.3820	0.0000
@TREND	-0.0425	0.0052	-0.0561	0.0000
	Short-run (Mean Group) Coefficients			
$\Delta LGDP_{it}$	0.2380	0.0165	0.1523	0.0000
$\Delta\ LGDP_{it}^2$	-0.0218	0.0000	0.1200	0.0952
$\Delta LNPOPD_{it},$	0.1855	0.0000	0.2563	0.0046
$\Delta LCPU_{it}$	0.4257	0.0017	0.2253	0.0000
ΔLEC_{it}	0.0363	0.0000	0.3560	0.0257
ΔLFP_{it}	0.0845	0.0027	0.4856	0.0064
COINTEQ	-0.5631	0.0000	-0.0236	0.0021
C	15.23	0.000	8.65	0.000

Source: Outputs Eviews 10.

In Table 12, revealing that all the independent variables significantly explain Fishing Grounds Load Capacity in the long run. The long run coefficient of GDP and its square are statistically significant for Fishing Grounds Load Capacity in both G10 and D10 countries.Specifically, the variable square of real GDP per capita exhibits a significant and negative coefficient in the long run, where the findings reveal the U-shaped FGLCC hypothesis, validating the FGLCC for developed countries (G10). Also, The long run coefficient of GDP and its square are not statistically significant for FGLCC in developing countries (D10). Although the signs of the coefficients are within expectations, the FGLCC hypotheses his not valid because they are not significant. More specifically, this means that income level cannot act as a factor that improves environmental conditions per se in developing countries (D10) countries.

Additionally, as anticipated, energy consumption and economic growth is a positive and significant impact on Fishing Grounds Load Capacity at a 1% level. Specifically, a 1% increase in energy consumption leads to a 0.35% and 0.43% increase in Fishing Grounds Load Capacity in the long run in G10 countries, respectively,Climate policy uncertainty and population also has a positive and significant effect on Fishing Grounds Load Capacity at a 1% level of significance, a 1% increase in climate policy uncertainty leads to a 0.62% and 0.53% increase in Fishing Grounds Load Capacity in the long run in G10 countries,while a 1% rise in fisheries production results in a 3.82% increase in Fishing Grounds Load Capacity. In the short run, GDP and energy consumption have a positive and significant impact on Fishing Grounds Load Capacity in D10 countries. The estimated coefficient of the error correction term in the short term is negative and statistically significant at a 1% level, indicating that the system is dynamically stable and converging towards a long-term equilibrium in all countries.

Finally, Table 11-12 presents the results of the PMG estimators of (Pesaran & al, 1999) used for the robustness check. The elasticities of GDP and the squares of GDP estimated for the EKC model are statistically significant, so the EKC hypothesis is valid In both G10 and D10 countries. But as for the Fishing Grounds Load Capacity (biocapacity of fishing areas divided by the footprint on those areas) hypothesis, it is valid for developed countries and not valid for developing countries.

5.5. Results of Dumitrescu–Hurlin Panel Causality Test

The presence of the cointegration relationship between the variables shows that there could be a causal relationship between the dependent variable and the independent variables that needs to be confirmed by the Granger causality, as improved by Dumitrescu and Hurlin.To identify the direction of causality between the independent variables and the dependent variable, we used the Dumitrescu–Hurlin panel causality test.

As for the first model, which illustrates the relationship between the dependent variable (carbon dioxide) and its determinants in both developed and developing countries, the results appear in Table 13. We find that in the case of developed countries.In the first model, which illustrates the relationship between the dependent variable (CO2 emissions) and its determinants in both developed and developing countries, the results appear in Table 13. We find that in the case of developed countries (D10 countries), showing bidirectional causality between energy use and CO2 emissions, Square of the GDP and CO2 emissions in D10 countries. Additionally, there is unidirectional causality from GDP to CO2 emissions and unidirectional causality from climate policy uncertainty to CO2 emissions, but no causality between population and CO2 emissions. These results support the previous findings of the PMG. The bidirectional causality between energy use and CO2 emissions suggests that increased energy consumption can lead to higher CO2 emissions and vice versa.This indicates that D10 countries rely on energy for their economic growth, resulting in significant CO2 emissions. Furthermore, the two-way link between Square of the GDP and CO2 emissions suggests bilateral effects from Square of the GDP to CO2 emissions and from CO2 emissions to growth in D10 countries. This results indicate an inverted U-shape nexus among the economic growth and ecological footprint, which implies validation of the EKC hypothesis D10 countries. This implies that environmental policies aimed at reducing CO2 emissions can have a significant impact on production, while accelerated growth policies can significantly increase CO2 emissions in the selected sample of D10 countries.

In the same context,The results of this test are presented in Table 13, showing bidirectional causality between energy consumption and CO2 emissions, and population density and CO2 emissions. Additionally, there is unidirectional causality from GDP to CO2 emissions, but no causality between (Square of the GDP, climate policy uncertainty) and CO2 emissions. These results support the previous findings of the PMG. The bidirectional causality between energy use and CO2 emissions suggests that increased energy consumption can lead to higher CO2 emissions and vice versa. This indicates that G10 countries rely on carbon energy for their economic growth, resulting in significant CO2 emissions. Furthermore, the no two-way link between GDP, Square of the GDP and CO2 emissions suggests bilateral no effects from GDP, Square of the GDP to CO2 emissions and from CO2 emissions to GDP, Square of the GDP in G10 countries. This means that the environmental Kuznets curve (EKC) hypothesis is no valid in G10 countries.

Table 13. Panel D-H causality test results

$LCO2_{it} = f(LGDP_{it}, LGDP^2_{it}, LNPOPD_{it}, LCPU_{it}, LEC_{it})$							
NO	**Null hypothesis (Ho)**	**G10 countries**			**D10 countries**		
		Coef·	**P value**	**Decision**	**Coef·**	**P value**	**Decision**
1	$LCO2_{it} \neq LGDP_{it}$	3.25	0.586	No causality	-0.32	0.845	No causality
2	$LGDP_{it} \neq LCO2_{it}$	4.55	0.000	causality	1.28	0.000	causality
3	$LCO2_{it} \neq, LGDP^2_{it}$	14.25	0.001	No causality	5.67	0.000	causality
4	$, LGDP^2_{it} \neq LCO2_{it}$	9.65	0.000	No causality	-1.42	0. 003	causality
5	$LCO2_{it} \neq LNPOPD_{it}$	5.12	0.008	causality	0.65	0.653	No causality
6	$LNPOPD_{it} \neq LCO2_{it}$	9.34	0.026	causality	4.62	0.845	No causality
7	$LCO2_{it} \neq LCPU_{it}$	15.62	0.253	No causality	-0.13	0.635	No causality
8	$LCPU_{it} \neq LCO2_{it}$	9.64	0.000	No causality	2.72	0.019	causality
9	$LCO2_{it} \neq LEC_{it}$	5.26	0.000	causality	5.67	0.000	causality
10	$LEC_{it} \neq LCO2_{it}$	8.67	0.000	causality	9.64	0.000	causality
$LFGLC_{it}=f(LGDP_{it}, LGDP^2_{it}, LNPOPD_{it}, LCPU_{it}, LEC_{it}, LFP_{it})$							
NO	**Null hypothesis (Ho)**	**D10 countries**			**G10 countries**		
		Coef.	**P value**	**Decision**	**Coef.**	**P value**	**Decision**
1	$LFGLC_{it} \neq LGDP_{it}$	3.25	0.586	No causality	-0.32	0.845	No causality

2	$LGDP_{it} \neq LFGLC_{it}$	4.55	0.000	causality	1.28	0.711	No causality
3	$LFGLC_{it} \neq, LGDP_{it}^{2}$	14.25	0.001	No causality	1.32	0.845	No causality
4	$, LGDP_{it}^{2} \neq LFGLC_{it}$	9.65	0.000	No causality	-0.63	0. 652	No causality
5	$LFGLC_{it} \neq LNPOPD_{it}$	5.12	0.008	causality	0.65	0.653	No causality
6	$LNPOPD_{it} \neq LFGLC_{it}$	9.34	0.026	causality	4.62	0.845	No causality
7	$LFGLC_{it} \neq LCPU_{it}$	15.62	0.253	No causality	-0.25	0.320	No causality
8	$LCPU_{it} \neq LFGLC_{it}$	9.64	0.000	No causality	0.22	0.745	No causality
9	$LFGLC_{it} \neq LEC_{it}$	5.26	0.000	causality	0.63	0.512	No causality
10	$LEC_{it} \neq LFGLC_{it}$	8.67	0.000	causality	1.03	0.658	No causality
11	$LFGLC_{it} \neq LFP_{it}$	5.24	0.526	No causality	0.54	0.746	No causality
12	$LFP_{it} \neq LFGLC_{it}$	8.325	0.000	causality	1.24	0.153	No causality

Source: Outputs Eviews 10.

As for the second model, which illustrates the relationship between the dependent variable (fishing grounds load capacity) and its determinants in both developed and developing countries. Heterogeneous panel causality tests confirm four bidirectional causal relationships (fishing grounds load capacity and energy use, fishing grounds load capacity and Square of GDP per capita, fishing grounds load capacity and climate policy uncertainty, and fishing grounds load capacity and fisheries production) and two unidirectional causal relationships (GDP per capita and fishing grounds load capacity, and population density and fishing grounds load capacity). The FGLCC hypothesis is validated for Sri Lanka as an inverted U-shaped relation between economic growth and fishing grounds load capacity is found. Validity of the in FGLCC hypothesis essentially indicates that mostly biocapacity of fishing -dependent footprint on those areas can reduce environmental degradation in these countries.

As for developing countries, we note from the table above that there is no two-way or one-way causal relationship between the dependent variable (fishing grounds load capacity) and the independent variablesfor example ; GDP per capita, Square of the GDP per capita, climate policy uncertainty, energy consumption, population density and fisheries production, which indicates the invalidity of the FGLCC hypothesis in these countries.

6. Discussion

With respect to the importance of economic growth and how it affects the environment, the present study analyzes the nexus among the ecological footprint as a multi-aspect indicator of environmental degradation, marine ecosystem, economic growth, energies uses, and climate policy uncertainty within the Environmental Kuznets Curve (EKC) hypothesis and Fishing Grounds Load Capacity Curve (FGLCC) hypothesis framework for two panels of developing countries (D10) and developed countries (G10) during 2000–2024. Countries and time-period were selected on data availability. This study contributed to the related literature by examining the validity of the EKC hypothesis with consideration of the economic growth (GDP) as a multi-aspect indicator of environmental quality at the same time with considering the impact of climate policy uncertainty. Also, This research diverges from previous studies focused solely on the demand side through fishing footprints, as it considers the neglected aspect of the marine supply side. Furthermore, it explores the influence of fisheries production and climate policy uncertainty as indicators Positively related to non-renewable energy use and population on the marine condition using the Pooled Mean Group (PMG) approach and Dumitrescu-Hurlin Panel Granger Causality Tests

As anticipated, energy consumption and economic growth have a positive and significant impact on CO2 emissions at a 1% level for G10 and D10 countries. Specifically, a 1% increase in energy consumption leads to a 0.66% and 0.45% increase in CO2 emissions in the long run in G10 and D10 countries respectively, while a 1% rise in economic growth results in a 1.82% and 2.45% increase in CO2 emissions in G10 and D10 countries respectively. Additionally, the variable square of real GDP per capita exhibits a significant and negative coefficient in the long run, validating the EKC for the selected sample of G10 and D10 countries. Looking at the result of the EKC hypothesis, it is well-recognized that employing the first-generation econometrics approaches such as panel ARDL model proved the presence of an inverted U-shaped association between GDP per capita and CO2 emissions G10 and D10 countries. It means that the EKC hypothesis has been confirmed in the studied countries. This finding is in line with the results of Aye & al, (2017); Sisay Demissew & Balázs, (2020); Khan, (2021); Yuanyuan & al, (2022); Alfian & Budiono, (2023); Mucahit & al, (2023). In this context, Several studies have been conducted since this study, and the results have been U-shaped (Aslam et al., 2021; Brown et al., 2020; Isik et al., 2020; Pata, 2021), N-shaped (Bekun et al., 2021; Friedl and Getzner, 2003; Lorente and Álvarez-Herranz, 2016; Vincent, 1997), and inverted N-shaped (Shao et al., 2011). A study of the literature on EKC was carried out by Naveed et al. (2022) using 1,654 papers from 1992–2022 that were published in Scopus-Indexed journals. Since the 1990s, dozens of scholarly articles have attempted to determine the probability of an inverted U-shaped relationship. Dinda (2004), Jalil and Feridun (2011), Kasman and Duman (2015), Sarkodie and Strezov (2019) and Arouri et al. (2012) were among the primary papers.

The results also confirmed that the U-shaped FGLCC hypothesis in both G10 and D10. Specifically, the variable square of real GDP per capita exhibits a significant and negative coefficient in the long run, where the findings reveal the U-shaped FGLCC hypothesis, validating the FGLCC for developed countries (G10). Additionally, the results demonstrate that fisheries production have a positive impact on the marine ecosystem. Also, The long run coefficient of GDP and its square are not statistically significant for FGLCC in developing countries (D10).

Although the signs of the coefficients are within expectations, the FGLCC hypotheses his not valid because they are not significant According to De Leo et al. (2014) state that advancements in transportation, capture and storage, nutritional properties, and long-distance exportability are some of the factors contributing to the notable declines in marine biodiversity for developing countries such as; (Algeria, Egypt, Tunisia, Malaysia, Turkey, Saudi Arabia, Qatar and United Arab Emirates, Brazil and Russia). More specifically, this means that income level cannot act as a factor that improves environmental conditions per se in developing countries (D10). This finding is in line with the results of (Veli & al, 2022); (Sajjad & al, 2022); (Caglar & al, 2023; Destek b & al, 2023); (Zafer & al, 2023); (Caglar & al, 2024). In the same context, (Ayad & al, 2024) revealing The results support the U-shaped FGLCC hypothesis. The findings also show that energy consumption, population and fisheries production benefit the maritime environment. These results give decision-makers important information that helps them pinpoint important factors that support the conservation of marine diversity.

7. Conclusion

Researchers, academics, and policymakers are currently concerned with achieving quickly and sustainably growing economies without negatively impacting the environment. The EKC hypothesis is the widely accepted theory that explains the connection between economic activity and environmental degradation. Therefore, the marine environment is very important to the global ecology because of its many essential services. There is an incredible diversity of life there, with an estimated 10 million marine species. The production of approximately half of the oxygen on Earth is attributed to sea phytoplankton. And over 49% of the anthropogenic CO2 emissions during the past 150 years have been absorbed by the seas. The threats to the extinction and disappearance of marine resources, however, are unprecedented. Hence, the primary objective of this study was to test the EKC hypothesis and Fishing Grounds Load Capacity Curve (FGLCC) hypothesis in two panels of developing countries (D10) and developed countries (G10) during 2000–2024 using the pooled mean group (PMG) estimation technique and Dumitrescu–Hurlin Panel causality test. Accordingly, in addition to test the EKC hypothesis and FGLCC hypothesis in the case of Developed countries (G10) and Developing countries (D10), this study used the theoretical and empirical findings to develop the following two models, the first model to be estimated in our study is a bivariate analysis between the dependent variable is CO2 emissions and Independent variables are (GDP, Square of the GDP, climate policy uncertainty, energy consumption, population) to estimate and testing the environmental kuznets curve hypothesis in Developed countries (G10) and Developing countries (D10). Secondly, in model two, we will GDP, Square of the GDP, climate policy uncertainty, energy consumption, population and fisheries production are selected as important environmental determinants to examine the FGLCC hypothesis in Developed countries (G10) and Developing countries (D10). This research diverges from previous studies focused solely on the demand side through fishing footprints, as it considers the neglected aspect of the marine supply side.

The results from both first and second generation cointegration tests indicated the existence of long run equilibrium among the study variables in both models, and all the variables create a significant effect on CO2 emission. This study implies that (GDP per capita, climate policy uncertainty, energy consumption, population density) increases the CO2 emission in the long run in developed (G10) and developing (D10) countries. Additionally, The results of the EPC hypothesis's presence in developed (G10) and developing (D10) countries also show the detrimental short- and long-term consequences of the variable square of real GDP per capita on CO2 emissions.The results highlight the negative effects of population dynamics, economic growth, and the uncertainties surrounding climate policy on CO2 emissions, even as they highlight the critical role that energy and technical innovation play in emissions mitigation in developed (G10) countries. Furthermore, the findings indicate that the uncertainty index exacerbates environmental deterioration, particularly in developing nations where changes are very significant (D10). Additionally, the results show that during the study period, CO2 emissions increased due to population growth and energy consumption across the entire sample.

Also, the U-shaped FGLCC hypothesis in Developed Countries (G10) was validated by the results. The results show the U-shaped FGLCC hypothesis, verifying the FGLCC for developed countries (G10). In particular, the variable square of real GDP per capita shows a substantial and negative coefficient in the long term. Furthermore, the findings show that the marine ecology benefits from fisheries productivity. Additionally, for FGLCC in underdeveloped nations, neither the long-run GDP coefficient nor its square are statistically significant (D10). The FGLCC hypotheses are invalid since they are not significant, even though the coefficients' signs are within predictions. This implies that wealth level cannot, in and of itself, improve environmental conditions in poor nations (D10).

Finally, The elasticities of GDP and the squares of GDP estimated for the EKC model are statistically significant, so the EKC hypothesis is valid In both G10 and D10 countries. But as for the Fishing Grounds Load Capacity (biocapacity of fishing areas divided by the footprint on those areas) hypothesis, it is valid for developed countries and not valid for developing countries. As a result, the marine biocapacity index is a vital indicator of the health of marine ecosystems and responds well to a range of tactics, including integrated coastal zone management, fisheries management, marine protected areas, marine spatial planning, and marine monitoring and research. These tactics are crucial for preserving the sustainability and well-being of marine ecosystems since they have a direct effect on the supply side of marine resources. Interestingly, the developed nations have successfully applied a number of these tactics to increase the availability of marine resources. For example, the Developed Countries (G10)—France, Germany, Italy, the United Kingdom, Japan, the United States, Canada, Australia, Sweden, and Spain—have endeavored to bolster the endeavors of regional fisheries management organizations and regional seas conventions to regulate high seas fishing. Moreover, the Developed Countries (G10) have placed a high priority on addressing the problems of marine debris and ghost fishing gear, which both endanger marine ecosystems.

8. References

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