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Toward a Greener Future: Investigating the Environmental Quality of Non-Green Trading in OECD Countries

Anke van Ledden¹, Muhlis Can^{2,*} and Jan Brusselaers¹

¹ Department of Environmental Economics, Institute for Environmental Studies, Vrije Universiteit Amsterdam, Amsterdam 1081 HV, Netherlands; ankevedden@gmail.com (A.V.L.), janbrusselaers@hotmail.com (J.B.);

² Social Science Research Lab BETA Akademi, Istanbul, Turkey; muhliscaan@yandex.com (M.C.);

* Correspondence: muhliscaan@yandex.com

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Abstract

International trade is recognized as a key contributor to environmental degradation. However, researchers and policymakers do not distinguish between the trade of green and non-green products. The Non-Green Trade Openness Index was developed to examine the effect of non-green products on environmental quality. This study examines the effect of trading non-green products on environmental quality for 37 member countries of the Organization for Economic Co-operation and Development (OECD) from 2003 to 2016 in the context of the Environmental Kuznets Curve (EKC) framework. The results of the long-run estimation techniques employed (FMOLS, DOLS, Fixed and Random effects) confirm the EKC hypothesis and show a negative relationship between the Non-Green Trade Openness Index and greenhouse gas emissions, which serves as a proxy for environmental quality. This implies that when there is more non-green trade in OECD member countries, greenhouse gas emissions within these countries decrease. Dividing green and non-green products is important, empowering practitioners and policymakers to make informed choices and define a strategy for a sustainable future. Additionally, policy recommendations are provided to support policymakers in their efforts to combat climate change.



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1. Introduction

Climate change can be described as one of the most pressing challenges of our time [1, 2]. Undeniably, global warming is caused by human activities, and climate scientists stress the urgency for immediate action [3]. Due to unsustainable energy use, land-use change, and the current lifestyle of the world's population, the average global temperature has risen by 1.1°C (in 2011-2020 compared to 1850-1900). The consequences of global warming include extreme weather events, the melting of glaciers resulting in rising sea levels, and major risks to biodiversity, key infrastructure, and food

availability [4]. International trade is one of the human activities that has a major impact on the environment: it causes 20% of global carbon emissions [1]. Xu et al. [5] confirmed that, on average, 20-30% of global greenhouse gas (GHG) emissions are created by producing and transporting goods and services. This is largely because goods must be transported over longer distances. This transportation relies for a major part on fossil fuels: more than 95% of motorized transportation relies on oil as its primary energy source. The pumping of oil creates major environmental damage, such as polluted seas and wetlands [6]. According to the International Energy

Agency [6], oil is responsible for 45% of energy-related CO₂ emissions in the US, which is the world leader in oil production and consumption. Also, trade-related activities such as packaging and waste management require large amounts of energy, which in turn affects environmental quality [7].

The extraction of natural resources, such as minerals, timber, and fossil fuels, often leads to the overexploitation and depletion of ecosystems, resulting in significant negative effects [8–10]. Additionally, the trade of agricultural products like soybeans, palm oil, and beef drives deforestation, causing habitat loss, biodiversity decline, and increased GHG emissions [11, 12]. The quantity of food that is being traded globally is larger than ever, and seafood has the largest share [13]. This has led to overfishing, oil spills, and aquaculture-related diseases, weakening oceanic ecosystems and jeopardizing fishing-dependent communities [13]. Additionally, globalization has fueled illegal wildlife trade, posing extinction risks to species, threatening human society, and contributing to land degradation [14–16].

At the same time, international trade is an essential element in creating jobs and raising living standards and is cited as one of the crucial drivers of economic development for many countries [17–19]. The United Nations (UN) recognizes and acknowledges the benefits that arise from international trade. International trade can, for example, contribute to the introduction of clean technologies in developing countries, which has a positive effect on the amount of emissions [20]. Additionally, trade allows countries to focus on producing goods and services that have minimal environmental consequences, which can result in a more efficient use of energy and resources [21]. In 2015, the UN developed the Sustainable Development Goals (SDGs) to mitigate climate change [22]. They adopted a set of seventeen global goals, containing 169 targets, to deal with global issues such as poverty, inequality, climate change, and environmental degradation. Trade is reflected in goal 17, however, also in goals 8, 9, 10, and 12. The UN argues that trade functions as an engine for economic growth and reduces poverty and, therefore, as an important means to achieve the SDGs.

International trade is essential for the future, as it can play a vital role in the reduction of emissions [23]. Trade can improve access to environmentally friendly goods and technologies, and it can also help countries adapt to climate change. At the same time, however, actions need to be taken to reduce environmental degradation. It can be said that the relationship between international trade and the environment is complex. There are both beneficial and harmful consequences, but there is no

consensus among researchers regarding the net impact of international trade on the environment [1]. For that reason, it is important to understand the connection between economic development and environmental degradation. Beckerman [24] stated that even though economic growth leads to environmental deterioration in the early phase, in the end, the best and only way to reach a livable environment for the majority of nations is to become wealthy. This philosophy is the basis for the Environmental Kuznets Curve (EKC). This curve suggests that after an economy reaches a particular level of economic growth (at the cost of the environment), further growth leads to reduced environmental degradation [25].

Cole [26] explained the EKC hypothesis (the inverted U relationship) by the interaction between three effects: the scale, composition, and technique effect. The first phase is the scale effect, which states that as the size of the economy grows, the amount of pollution produced also increases. The composition effect states that when economies grow, the focus tends to shift away from heavy industry and towards light production and services, which are usually less reliant on resources. As a result, pollution (or pollution intensity) usually decreases. As environmental awareness and the economy grows, the economy transitions to cleaner technologies and there will be a greater need for environmental policies to combat and avoid environmental degradation [27]. The effect of these regulations should be to lower the number of resources required to produce products and services. This is known as the technique effect [26]. Researchers suggest that the EKC could arise from international trade because a rise in trade openness may lead to economic growth [28].

This research focuses on OECD member countries because 80% of global trade and investment comes from OECD member countries and OECD partners, making it a major actor. In 1948, the Organization for European Economic Co-operation (OEEC) was established to help rebuild Europe after World War II [29]. The organization expanded further from 18 to 24 members, and in 1961, the Organization for Economic Co-operation and Development (OECD) was formed. From 1994 to 2023, 14 more members were added, bringing the total number of member states to 38 as of 2023. The main tasks within the organization are to manage economic relations between member countries, manage international trade, liberalize trade and capital flows, align national economic policies and provide a framework for sharing information [29]. Member countries make up 63% of the global GDP, making it a very important economic organization within international trade (Office of the United States Trade Representative, n.d.). Also, international trade within the

OECD is growing, both export and import numbers are increasing [30]. While the international trade of OECD member countries is increasing, it can also be seen that the total greenhouse gas emissions emitted by these countries have decreased since 2007. These greenhouse gas emissions include carbon dioxide, nitrous oxide, methane, HFCs and PFCs, hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride and nitrogen trifluoride. This decrease is partly due to environmental policies, with the OECD being the first international organization to establish a so-called "Environment Directorate" in 1971 [29]. According to Kruse et al. [31], environmental policies have ended up being stricter in OECD member countries to respond to the rising global and local environmental challenges. This is evident in the 138% increase in environmental policy stringency in OECD member countries between 2000 and 2010 [31]. The OECD engages in achieving the previously mentioned SDGs by collaborating with member countries, partner countries, and various stakeholders to combat environmental degradation while promoting economic growth and prosperity [32]. Although the future of trade is unclear, it is almost certain that it will stay an integral part of our global economy [33].

The environmental consequences of trade are affected by a number of factors, such as the nature of the traded goods, production methods, and the adoption of sustainable measures by exporting and importing nations [34, 35]. Encouraging sustainable trade and enhancing environmental regulations can play an essential role in reducing the harmful effects of international trade and nurturing a global trading system that is more environmentally conscious [36, 37]. To achieve this, it's crucial to comprehend the impact of trading specific goods on environmental quality, thus necessitating the division of the international trade basket into green and non-green products.

Green products can be defined as "those increasing energy efficiency and minimizing environmental damage due to energy consumption" [38]. This type of product is less damaging in production or use compared to other products and contributes to environmental sustainability [38]. The OECD compiled a list (List of Environmental Goods (GLEG)) of products that are considered green, which includes a total of 248 products [1]. Examples of green products include equipment and instruments that monitor and measure the levels of specific liquids or gases, which are used in various industries such as oil and gas [39]. Another example is industrial or laboratory ovens and furnaces used for the removal of harmful substances. This can include the processing of household or radioactive waste. Products that are not on the

previously mentioned GLEG list are considered non-green [1].

Non-green products are the exact opposite: they do not contribute to the change to a sustainable global economy. Such types of products are likely to be subject to environmental policies and taxes [1]. These are primarily products that have a high carbon footprint in their production. This includes commodities from industries involved in the production or processing of fertilizer, metals, electricity, or petroleum [40]. As the proportion of non-green products within the international trade basket grows, it becomes increasingly challenging to achieve an environmentally friendly economy [1].

Researchers have conducted numerous studies to assess the effect of trade on the environment, and the trade openness index, which includes green and non-green products, is often used for these studies [38]. However, a distinction must be made between green and non-green products to be able to assess the impact of both groups separately, to identify the problem, and contribute to decision-making to meet the established climate goals. The primary goal of this research is to examine the effect of trading non-green products on greenhouse gas emissions as a proxy of environmental quality in a case study for 37 member countries of the OECD. In addition to the important role the OECD plays within international trade, growing imports and exports and declining greenhouse gas emissions are also reasons to analyze the effect of the international trade of non-green products for this group of countries.

This study makes a number of contributions to the current literature. Firstly, only one study has been carried out to assess the impact of non-green goods on the environment (e.g., Can et al. [1]). Secondly, several studies have looked at the impact of trade in the OECD sample. However, no studies have analyzed the environmental effect of trading non-green goods within this country group. Lastly, this study will attempt to find consistent empirical results using different panel techniques.

2. Literature Review

2.1. The Technique, Composition, and Scale Effect of Trade

There are three distinct effects differentiated within the EKC framework: the technique effect, the composition effect, and the scale effect [41]. The technique effect of trade is rooted in the hypothesis that once the income of a country exceeds a certain threshold, environmental regulations tend to become more stringent [42]. This

could encourage industries to adopt cleaner production techniques, which could lead to a reduction in emissions. Indicators such as carbon or ecological footprint, environmental quality, or environmental regulations are commonly used to analyze the technique effect [43–46]. As mentioned, this effect can have a positive impact on environmental quality, as lower trade barriers and higher trade openness enable the transfer of green technology, innovative management strategies, and knowledge [47]. One of the results of the technique effect is a reduction in environmental deterioration in developed nations, primarily as a result of their advanced degree of technology. A study by Liobikienė and Butkus [45] demonstrates that the variables GDP, trade, and urbanization contribute to reducing carbon emissions through energy efficiency. The study highlights the importance of technological advancements and improving energy efficiency as a key approach to addressing climate change.

There are also studies that use economic complexity as a proxy for the technique effect of trade. Economic complexity provides information about a country's technological level and economic structure, and this reflects the technique effect [48]. A study by Can and Gozgor [49] examined the validity of the EKC hypothesis by using economic complexity as a proxy for the technique effect of trade and discovered that the EKC hypothesis is valid, that there is a positive impact of energy consumption on CO₂ emissions and that a greater economic complexity decreases the level of CO₂ emissions in the long run. Therefore, they conclude that economic complexity is a significant indicator for suppressing CO₂ emissions [49]. Zhang [50] also examined the effect of the technique and concluded that this effect has a substantial effect on the carbon emissions avoided via imports. The technique effect had only a small impact on reducing carbon emissions through imports during certain periods, primarily because changes in energy intensity had a small effect. A study by Jena [42] found similar results, concluding that the technique effect is negative across all pollutants, which means that the use of certain production techniques and technologies tends to reduce pollution levels.

However, there are also studies that suggest that the technique effect of trade has an adverse effect on environmental quality. This is evident in the study conducted by Khan et al. [47], which analyzed the relationship between trade and the environment in Pakistan and found that the technique effect of trade has a negative impact on environmental quality, leading to reduced environmental degradation.

Before the technique effect of trade takes place, the EKC demonstrates the composition effect, which describes how emissions are influenced by the structure of a country's output, determined by trade openness and comparative advantage. When the amount of trade increases, a country will specialize in goods where it has a comparative advantage based on factor endowments (which depend on capital-labor intensity) and pollution regulation, which affects comparative advantage [42].

Several studies have examined the impact of the composition effect of trade on emissions using the capital-labor ratio or changes in export composition as a proxy. However, the results have been inconsistent, with some studies finding a small or no effect, while others suggest it depends upon a country's comparative advantage [51]. The mix of the types of commodities being traded and the level of emission intensity associated with them can give a more thorough understanding of the effect of trade openness on CO₂ emissions [52].

Research by Tsurumi and Managi [53] found a decreasing trend in the levels of SO₂ and CO₂ emissions in nations with a higher capital-labor ratio, indicating that a higher capital-labor ratio may contribute to better energy efficiency. Zhang [50] also confirmed this in his study on trade-related carbon emissions in China from 1987 to 2007, and the study by Ling et al. [52] is also in line with the above-mentioned results.

These results contradict the research by Cole [54], which reveals a negative correlation between energy intensity and the composition effect, as indicated by a country's capital-labor ratio. The new findings suggest that, on average, per capita energy consumption is likely to decrease due to trade liberalization, which involves the reduction of trade barriers. The results from Cole and Elliott [51] are also in line with this. There are also studies that use trade diversification or export concentration as a proxy for the composition effect of trade. For instance, Apergis et al. [55] investigated the short- and long-run effects of export product concentration on CO₂ emissions, validated the EKC hypothesis, and concluded that in most countries, a greater product concentration of exports results in lower CO₂ emissions. Can et al. [56] also confirmed their study of the EKC hypothesis by examining the effect of overall export diversification, extensive margin, and intensive margin on CO₂ emissions.

As Grossman and Krueger [57] suggested, the first effect within the EKC framework is the scale effect: free trade policies open up international markets, resulting in increased economic activity, higher industrial output,

and, therefore, economic growth [42]. There is a link between the size of economic activity, which refers to the scale effect, and environmental quality [45]. The scale of trade is generally represented by the trade openness index in the literature. According to researchers, an increase in trade openness causes CO₂ emissions to increase in the long term [58].

Lv and Xu [41] studied the effects of trade openness as well as urbanization on CO₂ emissions and found that trade openness has a positive effect on the environment in the short term but a negative effect in the long term. Rasoulinezhad and Saboori [59] confirmed this negative effect in their research about the relationship between trade openness, CO₂ emissions, and other macroeconomic variables. Therefore, this study also implies that a higher degree of trade openness is related to higher emissions [59]. The research by Zhang [50] supports this and demonstrates that due to an increase in China's exports, the scale effect (caused by a change in export volume) was responsible for a 163% increase in emissions.

On the contrary, several studies state that trade openness is positively and significantly related to renewable energy consumption, which in turn might contribute to lowering CO₂ emissions [55, 60, 61]. Ansari and Khan [43] used trade openness to examine the effect of trade on the ecological footprint and concluded that an increase in economic activity (scale effect) in Asian countries does not lead to a decrease in environmental quality. This is most likely because higher income levels facilitate the adoption of newer technologies, which can ensure cleaner production processes. A study by Al-Mulali et al. [62] also confirms that trade openness lowers CO₂ emissions in the long run.

2.2. The Trade of Non-Green Products

It is important to keep in mind that all the studies mentioned assessing trade openness or other trade indicators, and researchers did not differentiate between green and non-green products within the international trade basket. To divide the basket into green and non-green products, Can et al. [63] designed the Green Trade Openness Index (GOP index) based on the Core CLEG products (CLEG+), which is a list that includes forty environmental goods. In this study, the researchers examined the effect of trading green products on environmental degradation in 31 OECD countries over the period between 2007 and 2017 in the context of the EKC hypothesis. The findings support the EKC hypothesis, and the outcomes demonstrate that having green products in trade (as measured by the index) can reduce a country's ecological footprint [63].

Likewise, Can et al. [38] also investigated the effect of green openness on environmental quality. To analyze environmental degradation, they analyzed the ecological footprint per capita, which incorporates carbon footprint and other factors, such as income per capita, the quadratic form of income, energy consumption per capita, and the Green Trade Openness Index based on the OECD CLEG list. Their findings revealed that Green Openness played a crucial role in promoting environmental sustainability [38]. These findings line up with the findings of Can et al. [63]; however, this study distinguished itself by incorporating eco-friendly and environmentally preferable products in computing the Green Trade Openness Index. Lee et al. [64] also utilized the Green Trade Openness Index to investigate the effects of international trade in green products on the environment and found that green trade benefits the environment. Therefore, the authors suggest that removing obstacles to the trade of environmentally friendly goods can help improve environmental quality [64].

A variety of studies have applied the Green Trade Openness Index to analyze the environmental impact of trading green products. However, there is only one study examining the matter of trade in non-green products. Can et al. [1] developed the Non-Green Trade Openness Index and calculated this index for 25 EU countries for the years 2003 to 2016. This index is developed to research the influence of trading in non-green products on environmental quality. It represents the proportion of the total export and import of non-green products in a country's international trade basket to that country's gross domestic product. This study concludes that Non-Green Trade Openness has an adverse effect on environmental degradation in the EU. In other words, more non-green trade between EU countries and the rest of the world improves the environmental quality in the EU but will push pollution towards non-EU countries [1]. Recent research by Alvi et al. [65] also distinguished the international trade basket and concluded that trade in non-environmental goods increases emissions in high-income countries, and trade in environmental goods lowers emissions in the long run.

According to Can et al. [1], separating the global trade basket is crucial for practitioners and policymakers who are seeking a way to lead a country toward a sustainable future. As observed above, no research has examined the impact of trading non-green products on greenhouse gas emissions as a representative of environmental quality within OECD countries. In this context, this research fills up an important gap in the literature.

Table 1. Variables and data.

Variables Used	Symbol	Definition	Data Source
Greenhouse gas emissions	GHG	Total greenhouse gas emissions (CO ₂ , CH ₄ , N ₂ O, HFCs, PFCs, and SF ₆) measured in kt of CO ₂ equivalent.	The World Bank
Gross Domestic Product per capita	GDPPC	Economic health measured by Gross Domestic Product per capita (constant 2015 US\$).	The World Bank
Gross Domestic Product per capita squared	GDPPC ²	Economic health measured by Gross Domestic Product per capita (constant 2015 US\$).	Author own calculation
Energy consumption per capita	ENERGYPC	Primary energy consumption measured in terawatt-hours.	Our World In Data
Non-Green Trade Openness Index	NGOP	Index of non-green trade within the international trade basket.	BETA Akademi Social Science Research Lab (SSR Lab)

3. Materials and Methods

In this study, we assess the impact of trading non-green products on the environment for countries that are part of the OECD based on data from 2003 to 2016. This study includes all OECD member countries except Luxembourg, as data regarding the Non-Green Trade Openness Index for Luxembourg is not available. The 14-year time frame is based on data availability of the OECD Statistics database, where the Non-Green Trade Openness Index is based on [1].

Panel data analysis is utilized in this study to analyze the correlation between trade (with a focus on non-green products) and environmental quality. Greenhouse gas (GHG) emissions intensity serves as a proxy for environmental quality and includes carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and fluorinated gases (F-gases). These gases are the dominant drivers of climate change and are primarily released into the atmosphere due to the manufacturing, transport, and waste associated with goods [66, 67]. The definition and data source of these variables can be found in Table 1.

3.1. Econometric Model

The EKC hypothesis is employed as a framework and the variable GHG serves as a proxy for environmental quality. Following Can et al. [1] and Can, Jebli et al. [63], the econometric model is estimated in Equation 1.

$$EQ_{i,t} = \beta_0 + \beta_1 GDPPC_{i,t} + \beta_2 GDPPC^2_{i,t} + \beta_3 ENERGYPC_{i,t} + \beta_4 NGOP_{i,t} + \varepsilon_{i,t} \quad (1)$$

Where *EQ*, *GDPPC*, *GDPPC²*, *ENERGYPC*, and *NGOP* represent environmental quality, gross domestic product per capita, square of gross domestic product per capita, energy consumption per capita, and Non-Green Trade Openness Index, respectively. In the formula, *i* represents the OECD member country and *t* stands for a given period (year). Lastly, ε is the error term. The variables *GDPPC* and *GDPPC²* represent the economic growth aspect of the relationship, and *ENERGYPC*

represents energy consumption. The variable *NGOP* captures the potential influence of the international trade of non-green products on environmental quality. This research intends to discover how these variables interact in relation to the dependent variable *GHG*.

3.2. Econometric Methodology

3.2.1. Diagnostic Tests

Multiple diagnostic tests are performed to analyze different aspects of the panel data. First, we perform the test for Cross-section Dependence (CD), using Pesaran [68], in the panel data. Performing this test can help ensure that the correlations between the variables remain consistent over time [68]. Thereafter, we applied the slope homogeneity test of Pesaran and Yamagata [69] to see if the panel data was homogeneous or heterogeneous. If the slopes of the regression lines are not homogeneous, then the outcomes of the unit root, cointegration, and long-run tests may be inaccurate or unreliable. So, as with the CD test, the outcome plays a key part in the selection of the following empirical methodology [38].

After completing the two essential tests, we perform the unit root process. In order to address the issue of biased regression, it is essential to conduct a unit root analysis prior to engaging in a cointegration analysis. The Pesaran [70] Cross-sectional Independence Panel Unit Root (CIPS) test is conducted. This test is selected because it takes into consideration heterogeneity and cross-sectional dependency [70]. A cointegration technique is applied to analyze the relationship between the variables over an extended period of time. When variables are cointegrated, it implies they have a lasting relationship and tend to move together over time, even if they may temporarily diverge. In this study, three different tests are employed: the Durbin-Hausman Cointegration Test developed by Westerlund [71], the Kao Residual Cointegration Test [73] and lastly, the Pedroni Residual Cointegration Test is employed [74]. We use these tests to investigate the presence of long-term relationships

Table 2. Descriptive statistics.

Variables	GHG	GDPPC	GDPPC ²	ENERGYPC	NGOP
Mean	-2.0336	4.4106	19.5436	5.7502	1.7614
Median	-2.0175	4.5189	20.4205	5.6277	1.7370
Max.	-1.5231	4.9274	24.2795	7.4324	2.2403
Min.	-2.5810	3.6172	13.0841	4.5451	1.2145
Std. Dev.	0.2078	0.3001	2.6086	0.6342	0.2201

Note: Panel data from 2003-2016, 14 years, countries 37, observations = 518.

Table 3. Cross-sectional dependence test.

Variables	GHG	GDPPC	GDPPC ²	ENERGYPC	NGOP
The Breusch-Pagan [72] LM test	5138.654*** [0.0000]	5501.826*** [0.0000]	5497.477*** [0.0000]	4144.777*** [0.0000]	3082.545*** [0.0000]
The Pesaran et al. [69] bias-adjusted LM test	121.127*** [0.0000]	131.078*** [0.0000]	130.959*** [0.0000]	93.895*** [0.0000]	64.790*** [0.0000]
The Pesaran [68] CD test	28.381*** [0.0000]	59.646*** [0.0000]	59.607*** [0.0000]	6.619*** [0.0000]	34.730*** [0.0000]

Note: *** implies the rejection of the null hypothesis at the 1% significance level.

Table 4. Slope homogeneity test.

Name of Tests	LM Stat.	p-value
Delta	18.243	0.000***
Adjusted Delta	24.133	0.000***

Note: *** shows 1% significance.

among the variables and to understand the underlying dynamics and interactions among the variables.

3.2.2. Long-Run Estimation Tests

After applying the cointegration tests, we conduct tests to determine the long-run coefficient of the independent variables. Long-run analysis is important as it enables more accurate predictions of the data, contributes to informed decision-making, and contributes to the overall understanding of the variables under investigation. Panel Fully Modified Least Squares (FMOLS) developed by Pedroni [75, 76] and Panel Dynamic Least Squares (DOLS) [77] are employed. We take on the DOLS approach to eliminate a possible correlation between the variables and the error term and to verify the results obtained from the FMOLS approach [78]. To verify the results, we also employ Fixed and Random effects. These methods collectively allowed for comprehensive and reliable long-run estimation in the panel data analysis conducted in this study.

3.2.3. Causality Analysis

After completing the long-run analysis, the objective of the causality analysis is to examine the short-term relationship between the variables. To explore the direction of causality between the variables, we conducted the Pairwise Dumitrescu Hurlin Panel Causality Tests [79]. This test is designed for heterogeneous panel data models and assumes a null hypothesis of homogeneous non-causality [79].

4. Results and Discussion

4.1. Descriptive Statistics

Table 2 shows the descriptive statistics for all variables used. For the variables, Greenhouse gas emissions (GHG), Gross Domestic Product per capita (GDPPC), Gross Domestic Product per capita squared (GDPPC²), Energy consumption per capita (ENERGYPC), and Non-Green Trade Openness Index (NGOP), the mean, median, maximum, minimum, and standard deviation are presented.

4.2. Cross-Sectional Dependence

Testing for cross-sectional dependency is important to select suitable unit-root and cointegration analysis approaches. In this study, three different types of tests [68, 69, 72] for cross-sectional dependency have been carried out to examine the null hypothesis of 'cross-sectional independence'. The results obtained from these tests are presented in Table 3. The outcomes indicate that the null hypothesis is rejected at a significance level of 1% for all variables. These results imply that there is a robust presence of cross-section dependency between the variables.

4.3. Homogeneity Test

In panel studies, it is important to apply the slope homogeneity test in order to select suitable unit root and cointegration techniques [63]. Therefore, the slope homogeneity test from Pesaran and Yamagata [80] is conducted, and the outcomes (Table 4) indicate that the null hypothesis of slope homogeneity is rejected at a 1% significance level. Therefore, the alternative hypothesis of 'heterogeneous slope coefficients' is verified. This suggests that the relationships between the independent

Table 5. Testing the order of integration of the variables (CIPS test for OECD Countries).

Variable	Level	First Difference	Critical Value	
			1%	5%
GHG	-1.759	-3.416***	-2.26	-2.11
GDPPC	-1.319	-2.264***	-2.26	-2.11
GDPPC ²	-1.288	-2.264 ***	-2.26	-2.11
ENERGYPC	-1.178	-3.463 ***	-2.26	-2.11
NGOP	-1.102	-3.077***	-2.26	-2.11

Note: ** and *** indicate rejection of null hypothesis at 5% and 1% significance levels, respectively; CIPS test based on Pesaran [70].

Table 6. Cointegration tests.

Variable	Test-stat	p-value	Weighted Statistic	p-value
Durbin-H Group stat	2.874	0.002***		
Durbin-H Panel stat	2.013	0.022***		
ADF	-2.0746	0.0190**		
<i>Alternative hypothesis: common AR coefs. (within-dimension)</i>				
Panel PP-Statistic	-0.5219	0.3009	-1.7895	0.0368**
Panel ADF-Statistic	-1.6947	0.0451**	-2.6307	0.0043***
<i>Alternative hypothesis: individual AR coefs. (between-dimension)</i>				
Group PP-Statistic	-2.8229	0.0024***		
Group ADF-Statistic	-3.7782	0.0001***		

Note: ***, **, and * indicate 1%, 5%, and 10% significance, respectively.

variables (GDPPC, GDPPC², ENERGYPC, and NGOP) and the dependent variable (GHG) vary across the entities in the panel dataset.

4.4. Unit Root Analysis

To determine if a unit root exists in the series, we employed the Pesaran [70] CIPS test. This test accounts for heterogeneity and cross-section dependence. We explored the null hypothesis, which presumes that the variables are non-stationary. The results (presented in Table 5) provide evidence that the series are not stationary in their level values. However, it is validated that all series come to be stationary when the first difference is taken. This means that the series contains a unit root. The variables GHG, GDPPC, GDPPC², ENERGYPC, and NGOP contain a unit root at I(0), while they become stationary at I(1) at a 1% significance level.

4.5. Cointegration Tests

The analysis proceeds by conducting different tests for long-run cointegration between the variables. The Durbin-Hausman Cointegration Test, Kao Residual Cointegration Test, and Pedroni Residual Cointegration Test are performed [71, 73, 75]. The null hypothesis for the Durbin-H test by Westerlund [71] is "there is no cointegration among variables" as opposed to the alternative hypothesis of "there is a cointegration among variables." According to the results, we reject the null hypothesis at a 1% significance level for both the Durbin-H Group and Durbin-H Panel statistics. To get robust results, we also employed the ADF test developed by Kao [73], which is an extension of the Augmented Dickey-

Fuller (ADF) test. We tested the null hypothesis of "there is no cointegration among variables". The results confirm the rejection of the null hypothesis at a 5% significance level. Lastly, the Pedroni Residual Cointegration Test is performed. The weighted statistic of the Panel PP-Statistic and Panel ADF-Statistic rejects the null hypothesis of "there is no cointegration among variables" at different levels of significance. This indicates strong evidence of cointegration within each variable in the panel dataset. The Group PP-Statistic and Group ADF-Statistic provide additional support for cointegration, as both reject the null hypothesis at a 1% significance level. The results from these three tests confirm that there is robust evidence of cointegration, suggesting a shared long-term relationship among variables. The results are presented in Table 6.

4.6. Long-Run Estimations

Results of the FMOLS technique (Table 7) confirm the EKC hypothesis, considering that GDPPC is positive (3.83) and GDPPC² is negative (-0.56). Both coefficients are statistically significant at a 1% significance level. Following the FMOLS approach, an increase of 1% in GDPPC increases GHG by 3.83%, and an increase of 1% in GDPPC² decreases GHG by 0.56%. These outcomes are in line with Can et al. [38], who also found a positive coefficient for GDP and a negative coefficient for GDPPC², confirming the EKC hypothesis. Can and Gozgor [49] also validated this hypothesis with a positive coefficient for per capita income, and a negative coefficient for the squared form of per capita income.

Table 7. Panel Fully-Modified Least Squares (FMOLS).

Variable	Coeff.	Std. er.	t-stat.	Prob.
GDPPC	3.8305	0.0253	151.4656	0.0000***
GDPPC ²	-0.5652	0.0343	-16.4771	0.0000***
ENERGYPC	0.4922	0.0200	24.6350	0.0000***
NGOP	-0.0386	0.0177	-2.1798	0.0298**

Note: ***, **, and * indicate 1%, 5%, and 10% significance, respectively.

Table 8. Panel Dynamic Ordinary Least Squares (DOLS).

Variable	Coeff.	Std. er.	t-stat.	Prob.
GDPPC	3.7374	0.6498	5.7514	0.0000***
GDPPC ²	-0.4559	0.0776	-5.8718	0.0000***
ENERGYPC	0.4997	0.0447	11.1687	0.0000***
NGOP	-0.0621	0.0330	-1.8786	0.0609*

Note: ***, **, and * indicate 1%, 5%, and 10% significance, respectively.

Table 9. Robust test with Random Effects and Fixed Effects.

Variable	Fixed Effects				Random Effects			
	Coeff.	Std. er.	t	Prob. t	Coeff.	Std. er.	z	Prob. z
GDPPC	2.2796	0.5114	4.46	0.0000***	2.1807	0.5133	4.25	0.0000***
GDPPC ²	-0.1152	0.0265	-4.34	0.0000***	-0.1134	0.0265	-4.28	0.0000***
ENERGYPC	0.6335	0.0352	17.99	0.0000***	0.7964	0.0282	28.21	0.0000***
NGOP	-0.1189	0.0260	-4.58	0.0000***	-0.1082	0.0266	-4.06	0.0000***
C	-7.3741	2.4402	-3.02	0.0030***	-8.7573	2.4654	-3.55	0.0000***

Note: *** implies the rejection of the null hypothesis at the 1% significance level.

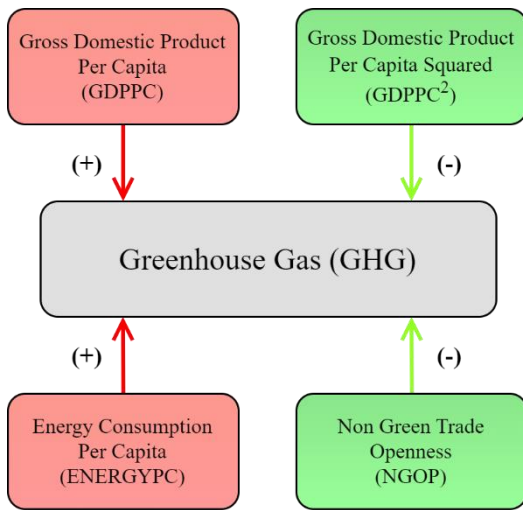


Figure 1. Results of long-run estimations.

ENERGYPC has a positive relationship with GHG. Following the FMOLS approach, an increase of 1% in ENERGYPC increases GHG by 0.49%. This coefficient is statistically significant at the 1% level. This is in line with Can and Gozgor [49] and Ling et al. [52], who also observed a positive relationship between energy consumption and CO₂ emissions. Ansari and Khan [43] also saw in their study that an increase in energy consumption comes at the expense of environmental quality; they identified a positive relationship between energy consumption and ecological footprint (a 1% rise in energy usage increases ecological footprint with 0.05% - 0.66%).

The core variable, Non-Green Trade Openness, has a negative relationship with GHG: when a nation's Non-Green Trade Openness increases by 1%, its greenhouse gas emissions will decrease by 0.03%. This coefficient is statistically significant at the 5% level. This outcome is in line with Can et al. [1], who also found a negative relationship between environmental degradation (quantified by ecological footprint) and non-green trade openness among a sample of 25 European countries (1% increase in NGOP results in a 349% decrease in ecological footprint).

We performed the DOLS analysis to obtain robust results. As shown in Table 8, the DOLS results also confirm the EKC hypothesis. Similar to the FMOLS analysis, GDPPC is positive (3.73), and GDPPC² is negative (-0.45). Both coefficients are statistically significant at a 1% significance level. ENERGYPC also exhibits a positive relationship with GHG in the DOLS analysis: a 1% increase in ENERGYPC leads to a 0.49% increase in GHG. Lastly, the DOLS analysis confirms the result of NGOP. The relationship between NGOP and GHG is negative, where a 1% increase in NGOP results in a 0.06% decrease in GHG, which is statistically significant at the 10% level. The results of the long-run estimates are shown schematically in Figure 1.

In addition, we employed both the Random Effects and Fixed Effects models to obtain more reliable and robust results, which are presented in Table 9. The results obtained confirm the validity of the EKC hypothesis once again and indicate that NGOP has a negative coefficient.

Table 10. Pairwise Dumitrescu Hurlin Panel causality test.

Null Hypothesis	W-Stat.	Zbar-stat.	Prob.
DGDPPC does not homogeneously cause DGHG	0.91191	-0.97538	0.3294
DGHG does not homogeneously cause DGDPPC	0.38490	-1.66467	0.0960*
DENERGYPC does not homogeneously cause DGHG	1.23475	-0.13479	0.8928
DGHG does not homogeneously cause DENERGYPC	1.23504	-0.13403	0.8934
DNGOP does not homogeneously cause DGHG	2.60210	3.48148	0.0005***
DGHG does not homogeneously cause DNGOP	1.11566	-0.44974	0.6529
DENERGYPC does not homogeneously cause DGDPPC	1.03531	-0.81398	0.4157
DGDPPC does not homogeneously cause DENERGYPC	1.42449	-0.30496	0.7604
DNGOP does not homogeneously cause DGDPPC	1.34178	-0.41314	0.6795
DGDPPC does not homogeneously cause DNGOP	0.28416	-1.79643	0.0724*
DNGOP does not homogeneously cause DENERGYPC	1.60239	0.83752	0.4023
DENERGYPC does not homogeneously cause DNGOP	0.74206	-1.43781	0.1505

Note: *** and * indicate 1% and 10% significance, respectively.

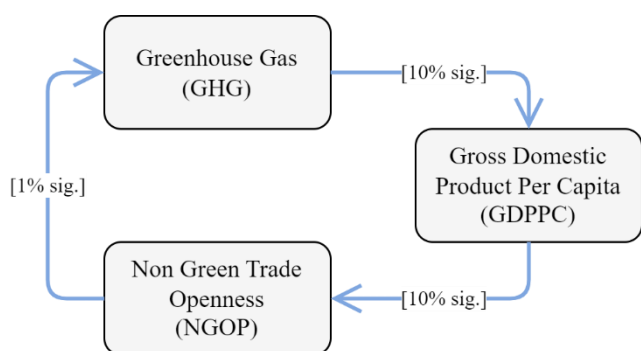


Figure 2. Results causality analysis.

4.7. Causality Analysis

To investigate the causality direction between the variables, we performed the Pairwise Dumitrescu Hurlin Panel Causality Tests [79]. The results, which can be found in Table 10, demonstrate significant unidirectional short-run causalities between GHG and GDPPC, as well as between GDPPC and NGOP, both at a 10% significance level. The results also reveal a unidirectional causality between NGOP and GHG at a 1% significance level. No bidirectional association or relation among other variables is found. The results are shown schematically in Figure 2.

4.8. Discussion

The positive coefficient for Gross Domestic Product per capita, the negative coefficient for Gross Domestic Product per capita squared, and positive coefficient for Energy consumption per capita findings support the idea that initially, as economies experience growth, greenhouse gas emissions tend to increase (scale effect of trade). However, after reaching a certain degree of development (indicated by the negative coefficient of Gross Domestic Product per capita squared), emissions start to decline (composition and technique effect of trade). Additionally, the positive coefficient for energy consumption is a contributing factor to greenhouse gas emissions. The negative relationship between the Non-

Green Trade Openness Index and greenhouse gas emissions suggests that when OECD member countries engage in international trade with a higher proportion of non-green goods, there may be a positive environmental impact within these countries.

As mentioned, the results suggest that a rise in non-green trade has a positive effect on environmental quality. These results are in line with Can et al. [1], who also found that more non-green trade (of European countries with the rest of the world) resulted in improved environmental quality (within the EU). This raises questions about the relocation of polluting industries to non-OECD member countries, often developing nations. There are several factors that may contribute to this shift. These factors primarily include the rise in labor and resource costs, as well as the increase in stringent environmental regulations within OECD countries [81]. Stricter environmental policies place an additional burden on companies as they have to modify traditional production methods [81]. The costs associated with the modification of these methods are relatively high, which in turn weakens incentives for innovation. Consequently, firms may experience a slowdown in productivity growth in the short term, which can also be at the expense of profits [82]. More stringent regulations will promote environmental sustainability; however, they will also stimulate polluting industries to shift to nations with less stringent environmental policies.

The shift of polluting industries from countries with stringent environmental regulations to countries where these policies are less stringent, is called the Pollution Haven Hypothesis (PHH) [83]. As mentioned before, environmental policies have become more rigorous in OECD member countries as a response to the changing climate [31]. According to Gill et al. [84], the PHH takes place via international trade and foreign direct investment (FDI), however this hypothesis is criticized. There are studies that find evidence on behalf of the PHH,

confirming that firms do shift production to countries with weaker regulations [83]. There are also studies that found no conclusive results in the confirmation of this hypothesis, and they claim that trade and investment might have a positive effect on the environment in developing countries [84].

5. Conclusions and Policy Implications

5.1. Conclusions

This research attempted to explore the relationship between environmental quality evaluated by greenhouse gas emissions and gross domestic product per capita, gross domestic product per capita squared, Non-Green Trade Openness Index, and energy consumption per capita for 37 OECD member countries for the period from 2003 to 2016, utilizing the Non-Green Trade Openness Index. In line with previous studies, the coefficient of Gross Domestic Product per capita is positive, and Gross Domestic Product per capita squared is negative. These findings provide evidence in favor of the EKC hypothesis. Additionally, the outcomes obtained from the long-run estimation techniques reveal a positive coefficient of Energy consumption per capita, indicating that a rise in energy consumption increases greenhouse gas emissions.

The coefficient of Non-Green Trade Openness Index is negative, implying that non-green trade openness decreases the number of emissions. The results indicate that as the share of non-green products in international trade (measured by the index) increases, greenhouse gas emissions reduce within OECD member countries. In other words, the increase in trading non-green products for OECD member countries causes an increase in these countries' environmental quality. This is not necessarily a preferred outcome as this could lead to a decline in environmental quality worldwide, as pollution could be pushed towards non-OECD countries.

Further research is required to explore the underlying factors behind these results and to examine the relationship between economic growth, environmental regulations, and pollution levels. Additionally, extending this research to other country groups and distinguishing between developed and developing nations would offer a more comprehensive understanding of the effect of non-green trade on environmental quality.

The conclusions section should summarize the main findings and their implications. It should restate the research question(s) or hypothesis(es) and state whether they were supported or not. It should also discuss the significance of the findings for the field.

5.2. Policy Implications

Implementing policies that support the goals of mitigating climate change and achieving the SDGs is crucial. Promoting the trade of green products is essential for reducing emissions worldwide. Policymakers can employ various options to encourage green trade and mitigate the trade-in non-green products, including reducing tariffs and implementing stringent environmental regulations. Strengthening current environmental regulations and developing new ones is vital for mitigating GHG emissions and combating environmental deterioration. Transitioning polluting industries towards cleaner production methods and adopting green technologies is essential. Policy measures can stimulate this transition by making clean technologies more affordable and promoting investments in new green innovations. Global efforts and significant financial investments from both governments and private companies are necessary to address the challenges of global warming.

Fostering effective international cooperation, facilitated through international agreements, is crucial for reducing emissions worldwide. Implementing standards and requirements for products plays a vital role in ensuring a consistent and unified approach across all member countries and addressing challenges in voluntary cooperation and enforcing agreements. International collaborations are strengthened when countries recognize the mutual benefits of coordination and understand the potential disadvantages of not participating.

5.3. Limitations of the Study

It is essential to address the limitations of this study to ensure transparency, and mention opportunities for improvements in following studies. This research focused on examining the relationship between environmental degradation and the trade of non-green products within OECD countries. While the findings demonstrate a correlation between non-green trade and emissions, it is important to note that this study did not identify specific reasons behind this relationship.

Following this, it is important to acknowledge that this study focuses on the EKC hypothesis. For future investigations, it is recommended to explore the effect of NGOP on environmental quality by employing the PHH. This hypothesis investigates the possibility that countries with less strict environmental regulations bring in industries that contribute to higher pollution levels. Examining this hypothesis could provide additional insights into the relationship between economic development and environmental degradation.

Concluding, this study focuses on OECD member countries. To get a more comprehensive understanding of the impact of non-green trade on greenhouse gas emissions, this research could be extended to other groups of countries. Future research could also make a distinction between developed and developing countries.

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