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The Impact of Green Trade Openness on Air Quality

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Abstract

Environmental degradation is among the most pressing issues the world faces today. Air pollution is one of the many forms of environmental degradation and can drastically impact human health and ecosystem functioning. Research shows that rapid intervention strategies are required to achieve the environmental targets set out by international agreements. One strategy that has been widely accepted to combat this issue of environmental degradation is the introduction of green products. The adoption of green products can be increased through trade. However, knowledge of the impact of trading these products is limited. This study examines the relationship between the trading of green products and air quality in a case study of 33 Organization for Economic Cooperation and Development (OECD) member countries from 2003-2016. We employ several panel strategies, such as the Westerlund (2008) Durbin-H method for cointegration and the Method of Moments Quantile Regression (MM-QR). The trading of green products was proxied by the newly developed 'Green Openness Index.' Nitrous oxide (NO_x) and sulfur oxide (SO_x) emissions served as proxies for air pollution. The relationship between the variables was explored in the context of the Environmental Kuznets Curve (EKC). The cointegration analysis reveals that there is a long-run relationship among the series. Long-run estimations prove that the EKC hypothesis is valid for the analyzed series. Additionally, the empirical findings reveal that trading environmentally friendly products increases air quality while energy consumption decreases. We provide several policy suggestions based on the study's outcomes, such as supporting the trade liberalization of green goods, reducing tariff and non-tariff barriers for environmentally friendly products, and promoting the adoption of environmentally friendly goods by providing subsidies and other tax incentives to consumers.



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1. Introduction

The world is witnessing a staggering decline in environmental quality that jeopardizes the capacity of the environment to meet social and ecological needs. Environmental degradation is closely linked to climate change, and its importance has gained global attention in the past decades [1–4]. International institutions such as

the Millennium Ecosystem Assessment (MEA) and the Intergovernmental Panel on Climate Change (IPCC) provide annual reports on the topic, emphasizing the need for rapid intervention. According to the MEA [5], almost 60% of all ecosystems are deteriorating or are being used unsustainably. Additionally, the IPCC [6] states that the average worldwide temperature in 2020 was already 1.2°C higher than pre-industrial levels. This

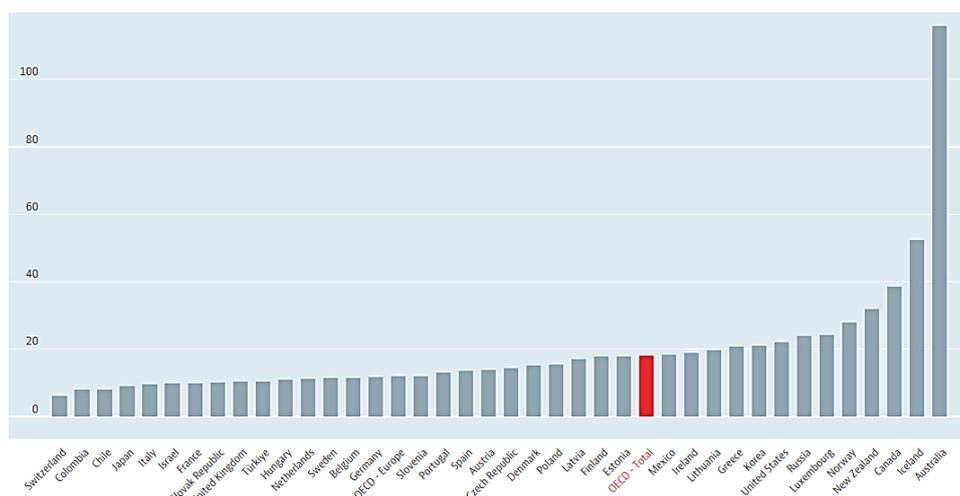


Figure 1. NOx emissions in kg/capita for OECD countries in 2020 (Source: OECD database [7]).

situation poses severe risks to the delicate balance of the planet's biophysical systems [8].

The environmental degradation seen today consists of many factors impacting the environment in different, complex ways [9–11]. Air pollution is one of these factors. With 99% of the global population breathing air that is polluted beyond World Health Organization (WHO) guidelines, it affects human health and ecosystem well-being [12]. The quality of water bodies and soil can be influenced by the precipitation of atmospheric pollutants [1]. Therefore, it can cause various environmental issues, such as acid rain, forest deterioration, photochemical smog, and reduced atmospheric visibility [13]. The most common air pollutants are sulfur and nitrogen-containing compounds and dust containing heavy metals such as lead and particulate matter (PM). The life expectancy of these compounds varies from hours to multiple months [1]. Many of these pollutants, such as sulfur dioxide (SO₂) and PM, travel long distances and have transboundary effects in regions that don't possess an emission source. Other compounds even have a global impact through the greenhouse gas (GHG) effect [14, 15]. Although carbon dioxide (CO₂) is the most widely known greenhouse gas, other air pollutants also contribute to the GHG effect and thus increase global warming [16]. Examples include PM, NO_x, and ozone. Ozone traps heat when it is present at ground level or at the top of the troposphere. Under these circumstances, it acts as a greenhouse gas [17]. Nitrous oxides can lead to the formation of ground-level ozone, thereby indirectly contributing to global warming [18, 19]. Black carbon is a component of PM that warms the earth's atmosphere by absorbing sunlight [20]. In addition to all the environmental issues, air pollutants can lead to various health problems. These health issues range from direct intoxication to Chronic Obstructive Pulmonary Disease (COPD), asthma, bronchiolitis, and lung cancer [21].

The majority of OECD member countries have recognized the need to reduce the emission of air pollutants for several decades [19]. The sources of air pollution vary per pollutant and are different across countries. Generally, the main contributors are energy transformation, energy consumption, and industrial processes [22–24]. The severity of air pollution in an area is determined by several factors, but densely populated areas, particularly, battle high degrees of total pollution [25–27].

NO_x is a group of poisonous gases that are highly reactive. This family of gases includes compounds such as nitrogen monoxide (NO) and nitrogen dioxide (NO₂). The majority of NO_x emissions consist of NO. These gases are created when fuel is combusted at high temperatures [18]. Therefore, the transport sector is one of the biggest sources of NO_x emissions in the OECD overall. NO_x pollutants are emitted by automobiles, trucks, boats, planes, and alternative vehicles that run on fuels such as gasoline and (bio)diesel. Other important sources are the manufacturing sector and the energy sector. Industrial facilities such as power plants, large-scale boilers, turbines, and manufacturing machinery emit large amounts of NO_x gases [28].

The distribution of the NO_x emissions per head of the population across OECD countries is depicted in Figure 1. The NO_x emissions per capita are highest in Australia, Iceland, Canada, New Zealand, and Norway. The emissions are smallest in Switzerland, Colombia, Chile, Japan, and Italy. Among other things, the emissions per capita depend on the economic structure, total population, and the country's energy resources. A country with a very high total NO_x emission can end up on the lower side of the distribution if it has a sizable population. This is the case for Japan [29]. On the contrary, Iceland has one of the lowest total NO_x emission rates but high per capita emissions. This is due

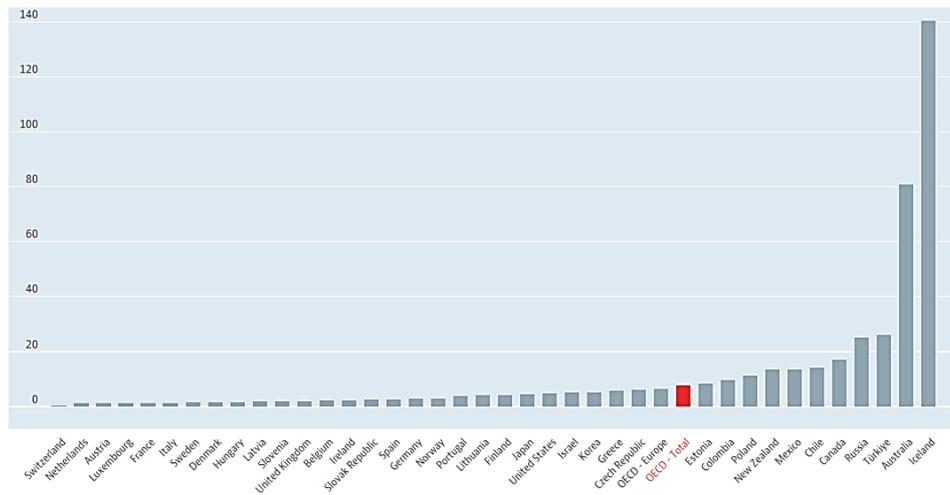


Figure 2. SOx emissions in kg/capita for OECD countries in 2020 (Source: OECD database [7]).

to the emissions of its large fishing fleet compared to a small population [30].

Sulfur oxides (SOx) are formed by the oxidation of sulfur (S), primarily through the combustion of sulfur-containing fuels [31]. Figure 2 depicts the distribution of SOx emissions per capita across OECD countries. In the OECD, electricity generation is the principal source of SOx emissions [32]. The five biggest emitters per capita are Iceland, Australia, Türkiye, Russia, and Canada, respectively. The countries that emit the lowest amount of SOx per capita are Switzerland, the Netherlands, Austria, and Luxembourg.

Although the emission of air pollutants has been decreasing in recent years, several challenges remain [33]. The first challenge is to further reduce local and regional emissions. Countries generally start with abatement activities that are relatively simple and low-cost. For example, it was agreed in the Gothenburg Protocol that countries with easy and affordable abatement opportunities would abate more than others. However, the costs of abatement increase for each additional unit of abatement. Abatement also becomes increasingly difficult technologically and more demanding from a policy perspective [34, 35].

The second challenge is to decouple the emissions of air pollutants from further economic growth. Decoupling is popular among policymakers as it promises to simultaneously achieve economic development and environmental protection. 'Green growth' is one of the hallmarks of the current OECD sustainability policy course [36]. The empirical evidence on decoupling emissions of air pollutants varies across countries, pollutants, and time periods. However, the consensus is that current decoupling rates are insufficient for environmental gain [37]. The third challenge is limiting people's exposure to polluted air. Countries often try to

achieve this through city planning and in-home improvements [32].

Since human activities generally form the primary source of environmental issues, it is necessary to find ways to reduce their detrimental impact [38–40]. In particular, economic activities that lack knowledge and skills affect societies as a whole [41]. Among these activities, the role of trade is significant and has the potential to influence environmental quality [42]. International trade has benefited countries through economic expansion and the introduction of foreign goods, services, and technologies [43]. Conversely, economic growth, increased resource use, and waste production associated with trade can negatively affect the environment [39, 44]. The nexus between trade and the environment has been a topic of research for several decades. However, the scientific community has not yet reached a consensus on it [9, 45].

Environmentally friendly or green products are designed to minimally impact environmental quality. Therefore, they are widely accepted as a tool to minimize environmental degradation from human activities [46]. Generally, the primary or secondary goal of producing an environmental good is to monitor, prevent, regulate, remove, or even reverse environmental harm [47, 48]. Similar to some non-environmentally friendly products, not all countries have the resources and capacity to produce green goods domestically. Therefore, international trade is vital to promote the further spreading and adoption of these products [49].

The trading of environmentally friendly goods has only recently emerged as an important field of study, and little is known about its impact on the environment [50, 51]. In addition, there is no consensus on what defines a green product, and an array of definitions and accompanying product lists can be found in the literature [52]. Many

scholars who examine the trade-environment nexus use the Trade Openness Index, which ignores the nature of products and does not distinguish between green and non-green goods. To assess the impact of trading green products specifically, Can et al. [50] presented the Green Openness Index (GOP) to measure the importance of green trade in a region. However, the GOP has only been applied to a limited number of indicators of environmental degradation, such as the ecological footprint.

Even though trade can play an important role in spreading green products, which are widely accepted as a tool to mitigate environmental degradation, most literature ignores the nature of the traded goods. Studies on the impact mechanisms of green trade on air quality are limited. The studies that do address this subject use an array of proxy indicators to assess the importance of green products in a country. This practice complicates the comparison of results. The Green Openness Index is a potential solution to this issue but has not yet been applied to air quality. Lastly, many scholars who find that trade improves air quality mention that technology transfer and the indirect effects of access to improved technology play a significant part in this result. However, to the best of our knowledge, no research has yet been conducted on the impact of green openness on air quality.

Therefore, this study aims to examine the impact of green trade on air quality in a case study of 33 OECD countries from 2003 to 2016. The Green Trade Openness Index (GOP) is the indicator for green trade as the core variable. This research makes several contributions to the literature. First, to the best of our knowledge, this study addresses the impact of green trade on air quality using the Green Openness Index in the OECD sample. Secondly, although there are studies in the literature that examine the relationship between green trade and the environment, it can be said that these studies are limited. In this context, this study provides an opportunity to expand the existing literature. Third, the study employs advanced panel technical methods. The consistency of these methods is tested by using two different dependent variables. Fourth, it provides several policy suggestions based on the empirical findings of green trade openness and air pollution.

The rest of this study is organized as follows. First, Section 2 discusses the empirical findings of the research covering trade, air quality, and green products. Section 3 introduces the EKC-based model and explains the econometric approach. Then, the results from the empirical analysis are reported and discussed in Section 4. Afterward, we provide policy recommendations based

on our findings in Section 5. Lastly, Section 6 concludes the study.

2. Literature Review

The impact of trade on environmental degradation depends on a multitude of factors. Generally, trade is closely associated with activities such as production, consumption, and transportation, which can cause environmental damage. These activities can deplete natural resources, emit greenhouse gases, and generate waste, which in turn causes issues like ecosystem deterioration, loss of biodiversity, and global warming [53]. For this reason, many scholars have studied trade and its impact on the environment. Despite decades of research, results are conflicting, and the extent of the impact of trade remains highly debated. The majority of scholars focus on CO₂ emissions and greenhouse gases as a proxy for environmental quality [54]. However, environmental degradation consists of many factors, and the relationship with trade must be unraveled before we can understand the impact of trade on the environment. Air quality is one of the factors that remains an important field of study as it is closely connected to the earth's ecosystems and climate [9, 15].

2.1. The Impact of Total Trade on Air Quality

Although the research is limited, the impact of trade on air quality has been explored by several researchers employing different methodologies. Most studies use concentrations of either one or multiple of the seven standard air pollutants as indicators for air quality. These pollutants are carbon dioxide (CO₂), sulfur dioxide (SO₂), ozone (O₃), nitrogen dioxide (NO₂), carbon monoxide (CO), lead (Pb), and particulate matter (PM). An increasingly employed indicator is visibility, determined by the density of gases and particles in the air. It is 'the greatest distance at which an observer can see a black object viewed against the horizon sky' [55].

Despite ongoing efforts, scholars are conflicted on the correlation between trade openness and air quality. Some suggest that trade openness has a beneficial effect on air quality (e.g., Antweiler et al. [56]), while others have concluded that trade has a detrimental effect (e.g., Li et al. [55], Yasmeen et al. [57], and Liu et al. [58]). The majority of research on the trade-environment nexus does not distinguish between the trading of green products and non-green products. Multiple researchers have criticized this situation, as green products are widely accepted as a tool to mitigate environmental degradation. Therefore, their impact should be explored separately from the total trade basket [51, 59]. A few studies specifically explored the impact of green trade on air quality.

China is the subject of multiple studies on air quality and green trade, as it is currently one of the world's major emitters of airborne pollutants, and 30% of its emissions are export-related [9, 60]. Trading green products reduces China's pollution levels of PM2.5 and several other environmental indicators, such as wastewater and solid waste. The country's increase in green international trade explains the recent decrease in pollution intensity, especially in green ordinary trade compared to green processing trade. Conversely, total trade is found to be harmful to air quality [58].

Another study on China shows similar results. Li et al. [54] analyzed firm-level trade data on 142 green products from 2007 to 2016. They employed a System Generalized Method of Moments (SYS-GMM) for their estimations. An increase in green imports and exports significantly improves air pollution measured in SO₂, while growth in total trade is associated with decreasing air quality. However, the correlation only applies to high-level trade regions and is negligible for low-level trade regions.

To the best of our knowledge, only three cross-country studies have been conducted on the nexus between trade in environmental goods and air pollution. The first is a cross-country study by Zugravu-Soilita [59]. It examines the impact of trading environmental goods (export + import in Green Products) on SO₂ emissions, CO₂ emissions, and biochemical oxygen demand (BOD). This was conducted for the transition economies of Central and Eastern Europe and the Commonwealth of Independent States from 1995 to 2003. Their model is constructed following the decomposition theory introduced by Grossman and Krueger [61]. The decomposition theory defines three pollution determinants: scale effect, composition effect, and technique effect. They applied a Durbin-Wu-Hausman test, and after that, the model parameters were estimated using a three-stage Least Squares Method (3SLS). Trade openness is examined as the scale effect. They found that green trade has no significant effect on SO₂ emissions; however, it increases water pollution and decreases CO₂ emissions.

De Alwis [62] performed another cross-country study that examined the impact of trade liberalization of Environmental Goods and Services (EGS) on air pollutants SO₂, NO_x, and CO₂. Trade liberalization was proxied by removing tariffs on EGS and non-EGS. The research used data from 62 countries from 2001 to 2008. The model they employed is based on Antweiler et al. [56]. In their research, they used Ordinary Least Squares (OLS) regression to estimate the model parameters. The study found that trade liberalization of EGS results in a decrease in SO₂ emissions. In addition, it revealed that air

pollution does not necessarily fall with green trade openness when a country holds a high-income level but when a country is capital-abundant. However, the estimated coefficient for the impact of green trade openness on NO_x emissions was insignificant.

In 2019, Zugravu-Soilita [63] conducted a follow-up study to her 2018 research on the same topic. This study covered 144 countries between 1996 and 2011. They checked the impact of trading environmental goods (import + export in Green Products) on CO₂ and SO₂ emissions through a multiple-equation Generalized Method of Moments (GMM) estimation. They used the same decomposition method based on Grossman and Krueger [61] as in their earlier study of 2018. Green trade was incorporated as the scale component. The results showed that such trade can lead to efficiency gains in CO₂ and SO₂ emissions per 1 US\$ of GDP. Conversely, green trade fails to provide environmental effectiveness regarding total CO₂ and SO₂ emissions. Therefore, the authors conclude that trade in environmental goods cannot effectively substitute non-market-based solutions. However, green trade can efficiently complement other non-market-based measures to reduce air pollution.

Although only a few studies have been conducted on the nexus between green trade and air quality, one can notice a difference in results compared to research on total trade. The results on the impact of total trade openness vary from a negative impact to a positive impact to an insignificant impact. However, none of the studies on green trade openness find evidence that it increases the emission of air pollutants. The outcomes only point to reduced emissions or the absence of impact.

2.2. Green Openness Index and Environment

The studies that examine the impact of green trade on air quality use an array of proxy indicators to assess the importance of green products in a country. This practice complicates the comparison of results across papers. Therefore, Can et al. [50] presented the Green Openness Index (GOP) to measure the importance of green trade in a region. Currently, seven studies use the GOP as an independent variable. One of these examines the impact of green openness on human well-being [51], and another explores the relationship between green trade openness and economic complexity in Central and Eastern European Union countries [64]. In total, five studies address the green openness-environment nexus. The following section discusses these five studies.

Most studies on GOP and the environment focus on OECD countries, and all find that green trade benefits the

Table 1. Definition of the variables.

Variable	Symbol	Description	Measurement	Data source
Air pollution	NOx	Nitrogen oxide emission intensity	Kg NOx per capita	OECD Database
	SOx	Sulfur oxide emission intensity	Kg SOx per capita	OECD Database
Income	IPC	Gross domestic product (constant prices 2015 US\$)	Income per capita	World Bank
Square of income	IPC2	Gross domestic product (constant prices 2015 US\$)	Income per capita	Own calculation
Energy consumption	ENPC	Consumption of primary energy	GJ per capita	International Energy Agency (IEA)
Green openness	GOP	Green trade openness	Index	BETA Akademi Social Science Research Lab

environment. Each scholar uses ecological footprint per capita, which includes carbon footprint and other components, as an indicator of environmental degradation. However, they employ different estimation techniques. For example, Can et al. [51] studied the impact of green trade on environmental degradation with panel data for 31 OECD countries from 2007 to 2017. The study employs panel cointegration techniques, a Granger causality test, and Pedroni (2004) based Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS). They found that increased green trade openness leads to decreased environmental degradation. The same result was obtained by Can et al. [65], who used a similar case study, model, and data but applied Westerlund [66] cointegration approaches and Augmented Mean Group (AMG), Pooled Mean Group (PMG), and Mean Group (MG) long-run estimators. They confirmed the previous findings presented by Can et al. [51]. Lee et al. [67] narrowed the scope to 24 EU countries between 2000 and 2018. They employed panel quantile regressions (QRs) and Driscoll-Kraay fixed effect-OLS regressions to analyze the relationships. The results showed that both green trade and economic complexity have a complementary synergistic beneficial impact on environmental quality.

Currently, only one GOP study has been performed outside the OECD group. Ahmad et al. [68] explored the dynamic relationship between technological innovation, green openness, financial inclusion, and CO₂ emissions for the BRICS countries (Brazil, Russia, India, China, and South Africa) from 2004 to 2018. Westerlund's [66] panel cointegration tests and the Continuously Updated and Fully Modified (CUP-FM) technique were used to explore the long-run relationship between the variables, in addition to Dumitrescu and Hurlin's [69] causality test. They showed that financial inclusion causes environmental degradation in the BRICS countries. Conversely, green openness and technological innovation mitigate CO₂ emissions.

3. Materials and Methods

3.1. Model Construction and Data

The empirical analysis aims to estimate the impact of trading green goods on air quality for 33 OECD countries. Due to insufficient data availability, the OECD members Costa Rica, Mexico, Chile, Colombia, and Luxembourg were excluded from the analysis. The studied timeframe covers 2003–2016, as this is the time limitation of the Green Openness Index.

Several air pollutants are commonly used as proxies for air quality, namely SOx emission intensity, NOx emission intensity, and PM emission intensity. This study will rely on NOx and SOx as the main indicators of air quality because the majority of OECD members have consistently reported their NOx and SOx emissions for over two decades [19]. Initial estimates in empirical models will be applied using NOx. Then, SOx emissions will be used to carry out a robustness check in the final stage of the analysis. The study specifically explores the influence of the Green Trade Openness Index on air quality while controlling for other potential factors, such as income and energy consumption. The different variables, their descriptions, and respective data sources are summarized in Table 1.

The Environmental Kuznets Curve model developed by Grossman and Krueger [61] is used as the theoretical framework for this analysis. Following van Hek et al. [70] and Can et al. [51], the EKC model is constructed in Formula 1 and 2:

$$NOx_{i,t} = \beta_0 + \beta_1 IPC_{i,t} + \beta_2 IPC2_{i,t} + \beta_3 ENPC_{i,t} + \beta_4 GOP_{i,t} + e_{i,t} \quad (1)$$

$$SOx_{i,t} = \beta_0 + \beta_1 IPC_{i,t} + \beta_2 IPC2_{i,t} + \beta_3 ENPC_{i,t} + \beta_4 GOP_{i,t} + e_{i,t} \quad (2)$$

Where NOx, SOx, IPC, IPC2, ENPC, and GOP stand for nitrogen oxide emission intensity, sulfur oxide emission intensity, GDP income per capita, the square of GDP income per capita, energy consumption per capita, and

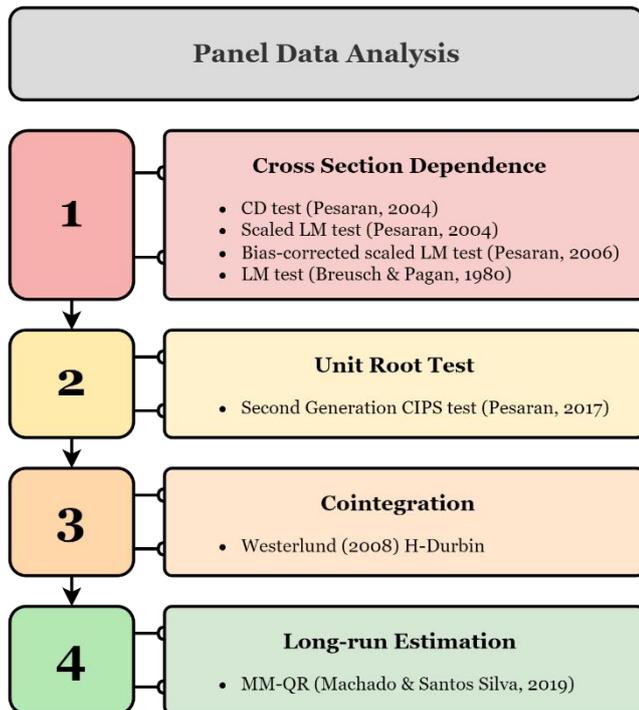


Figure 3. Methodological flowchart of the econometric analysis.

Green Openness Index, respectively. The i represents the country, t the time in years, and e the error term. The model parameters are the constant β_0 and the coefficients β_1 to β_4 .

3.2. Econometric Methodology

The EKC literature describes various econometric methods for estimating the coefficients in the model equations. This research used panel cointegration techniques to examine the relationship between green trade openness and air pollution. The research questions will be answered through a stepwise approach, as depicted in Figure 3.

3.2.1. Cross-sectional Dependence Test

Cross-sectional dependence (CD) tests are employed to check for the presence of cross-sectional dependence in the panel data. This is important because the economies of OECD nations are closely linked through international agreements and policies. Therefore, events in one nation can impact conditions in another. Additionally, the CD test results form the basis for selecting suitable panel unit root and cointegration procedures [71, 72]. The Breusch and Pagan LM, Pesaran scaled LM, bias-corrected scaled LM, and Pesaran CD tests were carried out for all variables [72]. In these tests, the null hypothesis states that 'there is no cross-sectional dependence across the series,' tested against the alternative hypothesis that 'there is cross-sectional dependence across the series.'

3.2.2. Unit Root Test

Unit root analysis was conducted prior to the cointegration analysis to address the issue of biased regression. If the series possesses a unit root, it is not stationary but dynamic, and standard models cannot be applied to it. The unit root must be removed from the time series before further analysis [73]. There are two types of unit root tests. The first considers the cross-sections in the panel data to be independent, while the second allows for cross-sectional dependence [74]. The cross-sectionally augmented IPS (CIPS) unit root test proposed by Pesaran [75] was employed because it accounts for CD in the estimation of stationarity. The null hypothesis states that 'the series has a unit root,' meaning the series is non-stationary. If the absolute value of the calculated CIPS test statistic is greater than the critical value, we can conclude that the series is stationary.

3.2.3. Cointegration Test

Panel cointegration tests explore the long-run relationship between the dependent and independent variables. The estimation builds on previous stages of the analysis, implying that the homogeneity of the parameters and the presence of any cross-sectional dependence must be considered [76]. Westerlund's [66] Durbin-H method was applied, along with a second-generation panel cointegration test that allows for cross-sectional dependence. This test transforms the variables by taking the difference from the cross-sectional averages. The Westerlund test requires that the dependent variable is $I(1)$ and the independent variables are $I(0)$ or $I(1)$. The null hypothesis states that 'there is no cointegration between the variables'.

3.2.4. Long-run Estimation

After cointegration between the series was established, the long-run coefficients were estimated using the Method of Movement Quantile Regression (MMQR) presented by Machado and Santos Silva [77]. This fixed effects quantile regression technique allows individual effects to influence the entire distribution. It is suited for panel data where $N > T$ (cross-sectional units are larger than time periods). Since traditional regression methods estimate the coefficients through average effects, they may underestimate or overestimate the coefficients, potentially missing important relationships. The main advantage of this method is that it is less sensitive to outlier observations and less susceptible to changes in variance. It can also provide efficient results in cases of skewness. Additionally, it captures heterogeneity across different quantiles of the dependent variable.

Table 2. Results of four cross-sectional dependence tests.

Variable	Breusch-Pagan LM	Prob.	Pesaran scaled LM	Prob.	Bias Adj. scaled LM	Prob.	Pesaran CD	Prob.
NOx	5505.7***	0.0000	153.18***	0.0000	151.91***	0.0000	69.659***	0.0000
SOx	5456.5***	0.0000	151.66***	0.0000	150.39***	0.0000	66.216***	0.0000
IPC	4220.8***	0.0000	113.64***	0.0000	112.37***	0.0000	51.642***	0.0000
IPC2	4217.1***	0.0000	113.53***	0.0000	112.26***	0.0000	51.611***	0.0000
ENPC	3956.6***	0.0000	105.51***	0.0000	104.24***	0.0000	26.996***	0.0000
GOP	2527.3***	0.0000	61.523***	0.0000	60.254***	0.0000	26.229***	0.0000

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

Table 3. Results of the CIPS unit root test.

Variable	CIPS Statistics I(0)	CIPS Statistics I(1)	Critical Value	
			1%	5%
NOx	0.0000	-3.1540***	-2.43	-2.21
SOx	0.0000	-4.0130***	-2.43	-2.21
IPC	0.0000	-2.4310***	-2.43	-2.21
IPC2	0.0000	-2.3260**	-2.43	-2.21
ENPC	-1.7300	-3.8710***	-2.43	-2.21
GOP	0.0000	-3.0520***	-2.43	-2.21

Note: ** and *** denote the rejection of the null hypothesis at the 5% and 1% significance levels, respectively. The CIPS test is based on Pesaran [75].

Table 4. Results of the Durbin-H Westerlund cointegration tests.

Independent Variable	Durbin-Hausman Group Statistics	Prob.	Durbin-Hausman Panel Statistics	Prob.
NOx	5935.8***	0.0000	10.361***	0.0000
SOx	12.144***	0.0000	19.969***	0.0000

Note: *** implies the rejection of the null hypothesis at the 1% significance level. The cointegration test is based on Westerlund [66].

4. Results and Discussion

4.1. Results of Cross-sectional Dependence Test

As mentioned above, CD is a crucial step for panel estimation. Thus, we employed different CD tests in the first step of our analysis. We conducted the Breusch-Pagan, Pesaran scaled LM, bias-corrected scaled LM, and Pesaran CD tests, respectively. The results of these CD tests are reported in Table 2. The findings provide evidence for rejecting the null hypothesis of cross-sectional independence. The variables are cross-sectionally dependent at the 1% significance level.

4.2. Results of Unit Root Test

In the second step of our investigation, we checked for unit roots among the series. The Pesaran [75] CIPS unit root test, conducted next, is suitable for panel data with cross-sectional dependence. The results are listed in Table 3 and indicate that the series are non-stationary at the level but stationary at the first difference. NOx, SOx, IPC, IPC2, and GOP are stationary at the first difference at the 1% significance level. Only the variable ENPC is

stationary at the first difference at the 5% significance level.

4.3. Results of Cointegration Test

It is critical to test for the presence of cointegration before we can perform regression on the series. We employed the Durbin-H Westerlund cointegration test [66] to examine the long-run relationship between the variables. This test allows for cross-sectional dependence and a large degree of heterogeneity. The null hypothesis assumes no cointegration between the series. The results are reported in Table 4. First, the test was carried out with NOx as the dependent variable. The p-values for the Durbin-Hausman Group Statistic and the Durbin-Hausman Panel Statistic were both found to be 0.000. These findings confirm the rejection of the null hypothesis at the 1% significance level. Therefore, we can conclude that there is a long-run relationship between the series. The same cointegration test was performed in the second stage with SOx as the dependent variable. Similarly, the p-values for the Durbin-Hausman Group Statistic and the Durbin-Hausman Panel Statistic were both found to be 0.000 for SOx. Therefore, the null

Table 5. Results of MM-QR regression for NO_x.

Variable	Low			Medium			High		
	Q _{0.10}	Q _{0.20}	Q _{0.30}	Q _{0.40}	Q _{0.50}	Q _{0.60}	Q _{0.70}	Q _{0.80}	Q _{0.90}
IPC	4.9892 [0.1070]	4.9188 [0.0590] *	4.8539 [0.0290] **	4.7996 [0.0160] **	4.7324 [0.0100] **	4.5944 [0.0280] **	4.5133 [0.0760] *	4.4517 [0.1320]	4.3959 [0.1910]
IPC2	-0.6487 [0.0720] *	-0.6416 [0.0350] **	-0.6349 [0.0140] **	-0.6295 [0.0070] *	-0.6227 [0.0040] ***	-0.6087 [0.0130] **	-0.6005 [0.0430] **	-0.5942 [0.0840] *	-0.5886 [0.1330]
ENPC	1.1431 [0.0000] ***	1.1321 [0.0000] ***	1.1219 [0.0000] ***	1.1135 [0.0000] ***	1.1029 [0.0000] ***	1.0814 [0.0000] ***	1.0687 [0.0000] ***	1.0591 [0.0000] ***	1.0504 [0.0000] ***
GOP	-0.3293 [0.0050] ***	-0.3262 [0.0010] ***	-0.3233 [0.0000] ***	-0.3209 [0.0000] ***	-0.3179 [0.0000] ***	-0.3119 [0.0000] ***	-0.3083 [0.0010] ***	-0.3056 [0.0060] ***	-0.3032 [0.0170] **

Note: The symbols *, **, and *** indicate the significance level at 10%, 5%, and 1% levels, respectively. Each pair of rows reports the coefficient estimate and the associated bootstrap standard error in parentheses for each quantile.

Table 6. Results of MM-QR regression for SO_x.

Variable	Low			Medium			High		
	Q _{0.10}	Q _{0.20}	Q _{0.30}	Q _{0.40}	Q _{0.50}	Q _{0.60}	Q _{0.70}	Q _{0.80}	Q _{0.90}
IPC	13.288 [0.0250] **	11.853 [0.0190] **	10.743 [0.0160] **	9.0701 [0.0160] ***	7.1988 [0.0360] **	5.5124 [0.1290]	3.6864 [0.3930]	2.3602 [0.6380]	1.0096 [0.8630]
IPC2	-1.6796 [0.0140] **	-1.5189 [0.0090] ***	-1.3946 [0.0070] ***	-1.2074 [0.0050] **	-0.9979 [0.0120] **	-0.8091 [0.0540] *	-0.6047 [0.2250]	-0.4562 [0.4300]	-0.3049 [0.6510]
ENPC	2.6202 [0.0000] ***	2.6918 [0.0000] ***	2.7472 [0.0000] ***	2.8307 [0.0000] ***	2.9241 [0.0000] ***	3.0083 [0.0000] ***	3.0994 [0.0000] ***	3.1656 [0.0000] ***	3.2323 [0.0000] ***
GOP	-0.6194 [0.0140] **	-0.6166 [0.0040] ***	-0.6144 [0.0010] ***	-0.6113 [0.0000] ***	-0.6077 [0.0000] ***	-0.6044 [0.0000] ***	-0.6009 [0.0010] ***	-0.5984 [0.0050] ***	-0.5958 [0.0160] **

Note: The symbols *, **, and *** indicate the significance level at 10%, 5%, and 1% levels, respectively. Each pair of rows reports the coefficient estimate and the associated bootstrap standard error in parentheses for each quantile.

hypothesis was rejected at the 1% significance level for this variable, confirming the existence of a long-run relationship between the series. Based on these results, we conclude that the cointegration estimation for NO_x is robust.

4.4. Results of Method of Moments Quantile Regression (MM-QR)

Next, we estimated the coefficients of our EKC model. This was done through the Method of Moments Quantile Regression (MM-QR) developed by Machado and Santos Silva [77]. The empirical results for the regression with NO_x as the independent variable are presented in Table 5. These results indicate that the real IPC and its square coefficients are positive and negative, respectively. This confirms that the EKC hypothesis is valid for this model. These coefficients are statistically significant at mixed levels (5% and 10%) in different quantiles. The IPC estimates for the 1st, 8th, and 9th quantiles are insignificant. For its square, the only insignificant estimation is in the 9th quantile. The other estimations

for these variables are statistically significant at mixed levels (1%, 5%, and 10%).

According to our results, energy consumption positively affects NO_x emissions and is significant at the 1% level in all quantiles. This is in line with our expectations since energy consumption is related to the process of combusting fossil fuels, which releases NO_x particles into the air [18].

Lastly, the results show that the impact of the core variable GOP on NO_x is significant at all quantiles. The estimated coefficients for the first eight quantiles are significant at the 1% level. Only the 9th quantile is significant at the 5% level. This means that green trading reduces NO_x and thereby positively affects air quality. This finding confirms our expectations since green products are expected to reduce air pollution through clean and resource-efficient technologies. Therefore, the trade of green products can be leveraged to improve air quality.

To check the robustness of the estimated regression for NO_x, we performed a secondary regression with SO_x as the independent variable. These regression results are depicted in [Table 6](#). The real IPC and its square coefficients are positive and negative, respectively. This confirms that the EKC hypothesis is also valid for this model with SO_x as the independent variable. The IPC coefficients are statistically significant at mixed levels (1% and 5%) in the 1st, 2nd, 3rd, 4th, and 5th quantiles. The estimations for the other quantiles are not significant. For the variable IPC squared, the estimation is significant at mixed levels (1%, 5%, and 10%) up to the 6th quantile. The higher quantiles yielded results that were not significant. Additionally, energy consumption positively affects SO_x emissions. The estimations for this variable are significant at the 1% level in all quantiles.

Lastly, the findings show that the impact of the core variable GOP on SO_x is also significant at all quantiles. The estimations for GOP are significant at the 1% level in the 2nd, 3rd, 4th, 5th, 6th, 7th, and 8th quantiles. Only in the 1st and 9th quantiles are the estimations for GOP significant at the 5% level. Our model results for SO_x emissions are similar to our NO_x emissions findings. Based on these findings, we conclude that the estimation for NO_x is robust.

4.5. Discussion

To our knowledge, this is the first study to describe the effect of GOP on air quality. Although similar studies are lacking in the existing literature, a few scholars have performed comparable research on the effect of green trade on NO_x or SO_x emissions specifically.

Our results showed that trading environmental goods can reduce NO_x and SO_x emissions. This outcome is in line with the findings of de Alwis [\[62\]](#) for 62 countries from 2001 to 2008. They concluded that the liberalization of green trade decreases SO_x emissions. However, this was only the case for countries that are capital-abundant. The majority of countries in which they made this particular observation are OECD countries. Many of the OECD countries are capital-abundant and possess a high capital-to-labor ratio [\[78\]](#). The estimated coefficient for the impact of their green trade openness indicator on NO_x was not significant. This contradicts our estimations for the GOP coefficient on NO_x emissions. This variation in results could be due to several reasons. For example, there is a difference in the construction of the indicator for green trade openness by de Alwis [\[62\]](#) and this study.

The study by Zugravu-Soilita [\[59\]](#) found that green trade (imports + exports) has no significant effect on SO_x emissions. Again, this outcome contradicts our results. Their study was performed for Central and Eastern

Europe and the Commonwealth of Independent States from 1995 to 2003. The majority of the analyzed nations are OECD member countries. However, the timeframe does not overlap with our study, which could be a reason for the difference in results. In addition, their model is not constructed following the EKC hypothesis. They follow the method of decomposition introduced by Grossman and Krueger [\[61\]](#). Green trade is examined as the scale effect. Such a vast difference in the construction of the model can cause contrasting outcomes between both studies.

The second study by Zugravu-Soilita [\[63\]](#) found that green trade does not significantly impact SO_x emissions. Green trade can lead to economic efficiency gains in terms of abatement costs of SO_x emissions. However, green trade fails to provide environmental effectiveness regarding total SO_x discharge. They used the same decomposition method based on Grossman and Krueger [\[61\]](#) as in their earlier study of 2018. Green trade was again incorporated as the scale component. This model required that the parameters be estimated through GMM. The study was performed in a timeframe similar to ours, covering 144 countries. Therefore, the majority of subjects are non-OECD member countries. The difference in research outcomes can be due to variations in subjects, models, or both.

As previously stated in the literature review, multiple scholars have suggested that the impact of green trade on air quality is likely to vary with the indicator, timeframe, and country [\[9, 15, 60, 62\]](#). The number of studies that are comparable to ours is very limited. None of the analyses exclusively cover OECD member countries. Income or the specific economic nature of a country can influence the outcomes. OECD members are often high-income countries with a high capital-to-labor ratio and a relatively large degree of green trade openness [\[78\]](#). These are all traits that some researchers believe are correlated with a beneficial impact of trade on air pollution [\[9, 15, 79\]](#).

5. Policy Recommendations

This study found that green trade openness plays a significant role in reducing air pollution, specifically NO_x and SO_x emissions. This is an important observation, as it illustrates that it is not just trade that affects a country's air quality; the type of traded products also determines how air quality is impacted.

Based on these findings, we present several policy recommendations for policymakers in OECD countries seeking to improve air quality. Given the wide variation among OECD economies, it is crucial to tailor the suggested policies to specific local circumstances. To

achieve air quality targets, policymakers should first formulate a long-term strategy to expand the trading of green products. Our empirical findings support the trade liberalization of green goods. Therefore, the most crucial step in such a plan is to reduce tariff and non-tariff barriers for environmentally friendly products [80]. This policy can potentially increase green trade and decrease the prices of green products in the market. Additionally, policies targeting a wide range of consumers and businesses tend to be more cost-efficient than those aimed at only one specific product or technology [19].

Another important step is to form new international agreements to further encourage green trade between countries. Trade liberalization through international cooperation and the removal of trade barriers can expand the green trading basket. Comparative advantage can lead to product specialization and, consequently, cost reductions [81]. Such cost reductions can make green goods more accessible to a larger consumer group, thereby increasing the sales market.

Additionally, policymakers should incentivize their country's manufacturing and adoption of green goods. For instance, governments can support the adoption of environmentally friendly goods by providing subsidies and other tax incentives to consumers. Consumers are also influenced by education and awareness campaigns. Education can raise awareness of the importance of green products [82]. Knowledge on this topic can encourage consumers to purchase green products instead of their non-green counterparts. Therefore, education and campaigns play an important role in expanding green trade. Another way to increase adoption is by providing loans and subsidies to consumers. Financial support can reduce the cost barrier for environmentally friendly products, facilitating the expansion of green trade and providing access to a more diverse assortment of green goods [83].

Alongside consumers, the government should support manufacturers and other businesses in the value chain of green products. The manufacturing of green goods can be assisted through financial incentives that lower total manufacturing costs. These incentives can take various forms, such as subsidies, grants, low-interest loans, or tax reductions [84]. Moreover, funding should be allocated for research and development projects. Supporting activities that promote the further development of environmental goods can lead to diversifying the green trade basket [83]. Technical advancements can also enhance the positive impact of green products on air quality. Ultimately, a collaborative approach can drive sustainable growth in the green economy.

Lastly, research indicates that stringent environmental regulations expand the green trade market [85]. When more stringent regulations are implemented, consumers and manufacturers are compelled to comply and adjust their practices, which increases demand for environmental goods and drives international green trade. Additionally, it boosts a country's specialization in green goods. Therefore, policymakers could consider formulating stringent green technological requirements for production machinery or household appliances.

6. Conclusions

Environmental degradation is recognized worldwide as one of the main contributors to climate change. A significant aspect of environmental degradation is air pollution. Not only does it contribute to global warming, but it also negatively affects human health and ecosystem functioning. In response, the international community is developing strategies to combat this issue, one of which is the introduction of green products. Green trade can facilitate the increased adoption of these products. However, knowledge about the environmental impact of trading such products remains limited.

In this study, we estimated the impact of green trade openness, energy consumption, and income on air quality in 33 OECD member countries between 2003 and 2016. We employed the Environmental Kuznets Curve (EKC) as a framework for constructing our model and applied several panel strategies, including the Westerlund Durbin-H method for cointegration and the Method of Moments Quantile Regression (MM-QR). The outcomes confirmed that the EKC hypothesis is valid for our series. Our MM-QR estimations indicate that our core variable, green trade openness, has a significant effect on air quality, suggesting that it can potentially be a useful tool in reducing air pollution.

Based on our findings, we presented several policy recommendations to the national governments of OECD member countries and international organizations concerned with air pollution. The proposed policies focus on expanding trade in green products. We believe that policies promoting international cooperation and trade liberalization are especially beneficial for the expansion of green trade. Additionally, policies should aim to remove production and adoption barriers for manufacturers and consumers, respectively. Education and raising awareness about the importance of environmental goods should be integral to any chosen policy direction.

There are various limitations to this study. First, the analysis focuses solely on OECD countries, where major differences exist between the economies of OECD and

non-OECD nations. Therefore, our conclusions may not apply to non-OECD countries, indicating a need for further research in this area. Another limitation is that air pollution comprises many chemical components, which cannot be fully represented by NO_x and SO_x emissions alone. Unfortunately, many other important constituents of air pollution, such as particulate matter, have not been consistently reported. To the best of our knowledge, there is no comprehensive air quality index available that could have served as an indicator in this analysis. Further research aimed at measuring air pollutants and constructing a robust air pollution index would greatly benefit studies in the field of air quality.

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References

- Ryabuhina, M. V., Maiski, R. A., and Kalyakina, R. G. (2019). Transboundary Air Pollution and Its Effects on Vegetation, *IOP Conference Series: Materials Science and Engineering*, Vol. 687, No. 6, 066043. doi:10.1088/1757-899X/687/6/066043.
- Tyagi, S., Garg, N., and Paudel, R. (2014). Environmental Degradation: Causes and Consequences, *European Researcher*, Vol. 81, No. 8–2, 1491. doi:10.13187/er.2014.81.1491.
- Hardi, I., Afjal, M., Can, M., Idroes, G. M., Noviandy, T. R., and Idroes, R. (2024). Shadow Economy, Energy Consumption, and Ecological Footprint in Indonesia, *Sustainable Futures*, 100343. doi:10.1016/j.sfr.2024.100343.
- Idroes, G. M., Rahman, H., Uddin, I., Hardi, I., and Falcone, P. M. (2024). Towards Sustainable Environment in North African Countries: The Role of Military Expenditure, Renewable Energy, Tourism, Manufacture, and Globalization on Environmental Degradation, *Journal of Environmental Management*, Vol. 368, 122077. doi:10.1016/j.jenvman.2024.122077.
- Millennium Ecosystem Assessment. (2023). Current State & Trend Assessment, from <https://www.millenniumassessment.org/en/Condition.html>.
- IPCC. (2021). Climate Change 2021: The Physical Science Basis, from https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_FullReport.pdf.
- OECD Database. (2020). Air and Climate - Air and GHG Emissions, from <https://www.oecd.org/en/data/indicators/air-and-ghg-emissions.html>.
- Oluc, I., Can, M., Eronal, Y., and Saboori, B. (2024). Assessing the Environmental Implications of Structural Change in Middle-Income Countries: Introducing the Structural Change Index, *International Journal of Environmental Science and Technology*, Vol. 21, No. 8, 6339–6356. doi:10.1007/s13762-023-05408-4.
- Van Tran, N. (2020). The Environmental Effects of Trade Openness in Developing Countries: Conflict or Cooperation?, *Environmental Science and Pollution Research*, Vol. 27, No. 16, 19783–19797. doi:10.1007/s11356-020-08352-9.
- Idroes, G. M., Hardi, I., Hilal, I. S., Utami, R. T., Noviandy, T. R., and Idroes, R. (2024). Economic Growth and Environmental Impact: Assessing the Role of Geothermal Energy in Developing and Developed Countries, *Innovation and Green Development*, Vol. 3, No. 3, 100144. doi:10.1016/j.igd.2024.100144.
- Idroes, G. M., Hardi, I., Rahman, M. H., Afjal, M., Noviandy, T. R., and Idroes, R. (2024). The Dynamic Impact of Non-renewable and Renewable Energy on Carbon Dioxide Emissions and Ecological Footprint in Indonesia, *Carbon Research*, Vol. 3, No. 1, 35. doi:10.1007/s44246-024-00117-0.
- World Health Organization. (2021). *Who Global Air Quality Guidelines: Particulate Matter (PM_{2.5} and PM₁₀), Ozone, Nitrogen Dioxide, Sulfur Dioxide and Carbon Monoxide*, World Health Organization.
- Xu, Y., Dietzenbacher, E., and Los, B. (2020). International Trade and Air Pollution Damages in the United States, *Ecological Economics*, Vol. 171, 106599. doi:10.1016/j.ecolecon.2020.106599.
- Ul-Haq, J., Visas, H., Can, M., and Khanum, S. (2023). How Diversification of Products Impact Emissions in China: A Provincial Perspective, *Environmental Science and Pollution Research*, Vol. 30, No. 59, 124215–124231. doi:10.1007/s11356-023-31078-3.
- Managi, S., Hibiki, A., and Tsurumi, T. (2009). Does Trade Openness Improve Environmental Quality?, *Journal of Environmental Economics and Management*, Vol. 58, No. 3, 346–363. doi:10.1016/j.jeem.2009.04.008.
- Fuzzi, S., Baltensperger, U., Carslaw, K., Decesari, S., Denier van der Gon, H., Facchini, M. C., Fowler, D., Koren, I., Langford, B., Lohmann, U., Nemitz, E., Pandis, S., Riipinen, I., Rudich, Y., Schaap, M., Slowik, J. G., Spracklen, D. V., Vignati, E., Wild, M., Williams, M., and Gilardoni, S. (2015). Particulate Matter, Air Quality and Climate: Lessons Learned and Future Needs, *Atmospheric Chemistry and Physics*, Vol. 15, No. 14, 8217–8299. doi:10.5194/acp-15-8217-2015.
- Shindell, D., Faluvegi, G., Lacis, A., Hansen, J., Ruedy, R., and Aguilar, E. (2006). Role of Tropospheric Ozone Increases in 20th-Century Climate Change, *Journal of Geophysical Research: Atmospheres*, Vol. 111, No. D8. doi:10.1029/2005JD006348.
- Fuglestedt, J. S., Isaksen, I. S. A., and Wang, W. C. (1996). Estimates of Indirect Global Warming Potentials for CH₄, CO and NO_x, *Climatic Change*, Vol. 34, No. 3–4, 405–437. doi:10.1007/BF00139300.
- OECD. (2020). Air quality - Environment at a Glance, from <https://www.oecd.org/environment/environment-at-a-glance>.
- Herndon, J. M., and Whiteside, M. (2019). Further Evidence that Particulate Pollution is the Principal Cause of Global Warming: Humanitarian Considerations, *Journal of Geography, Environment and Earth Science International*, 1–11. doi:10.9734/jgeesi/2019/v21i130117.
- Manisalidis, I., Stavropoulou, E., Stavropoulos, A., and Bezirtzoglou, E. (2020). Environmental and Health Impacts of Air Pollution: A Review, *Frontiers in Public Health*, Vol. 8. doi:10.3389/fpubh.2020.00014.
- Han, C. (2010). Strategies to Reduce Air Pollution in Shipping Industry, *The Asian Journal of Shipping and Logistics*, Vol. 26, No. 1, 7–29. doi:10.1016/S2092-5212(10)80009-4.
- Wieser, A. A., Scherz, M., Passer, A., and Kreiner, H. (2021). Challenges of a Healthy Built Environment: Air Pollution in

- Construction Industry, *Sustainability*, Vol. 13, No. 18, 10469. doi:10.3390/su131810469.
24. Hardi, I., Idroes, G. M., Hamaguchi, Y., Can, M., Noviandy, T. R., and Idroes, R. (2024). Business Confidence in the Shift to Renewable Energy: A Country-Specific Assessment in Major Asian Economies, *Journal of Economy and Technology*. doi:10.1016/j.ject.2024.08.002.
25. Chen, J., Wang, B., Huang, S., and Song, M. (2020). The influence of increased population density in China on air pollution, *Science of The Total Environment*, Vol. 735, 139456. doi:10.1016/j.scitotenv.2020.139456.
26. Castells-Quintana, D., Dienesch, E., and Krause, M. (2021). Air pollution in an urban world: A global view on density, cities and emissions, *Ecological Economics*, Vol. 189, 107153. doi:10.1016/j.ecolecon.2021.107153.
27. Noviandy, T. R., Hardi, I., Zahriah, Z., Sofyan, R., Sasmita, N. R., Hilal, I. S., and Idroes, G. M. (2024). Environmental and Economic Clustering of Indonesian Provinces: Insights from K-Means Analysis, *Leuser Journal of Environmental Studies*, Vol. 2, No. 1, 41–51. doi:10.60084/ljes.v2i1.181.
28. European Environment Agency. (2018). Nitrogen Oxides (NOx) Emissions, from <https://www.eea.europa.eu/data-and-maps/indicators/eea-32-nitrogen-oxides-nox-emissions-1/assessment.2010-08-19.0140149032-3>.
29. EANET. (2024). Unlocking and Future-Proofing Air Quality Management in Asia, from <https://www.eanet.asia/eanet-regional-workshop-2024-unlocking-and-future-proofing-air-quality-management-in-asia>.
30. European Environment Agency. (2014). Iceland - Air Pollution Country Fact Sheet, from <https://www.eea.europa.eu/themes/air/country-fact-sheets/2021-country-fact-sheets/iceland>.
31. Dignon, J. (1992). NOx and SOx Emissions from Fossil Fuels: A Global Distribution, *Atmospheric Environment. Part A. General Topics*, Vol. 26, No. 6, 1157–1163. doi:10.1016/0960-1686(92)90047-O.
32. Mujtaba, G., and Shahzad, S. J. H. (2021). Air Pollutants, Economic Growth and Public Health: Implications for Sustainable Development in OECD Countries, *Environmental Science and Pollution Research*, Vol. 28, No. 10, 12686–12698. doi:10.1007/s11356-020-11212-1.
33. Oluc, I., Ben Jebli, M., Can, M., Guzel, I., and Brusselaers, J. (2023). The Productive Capacity and Environment: Evidence from OECD Countries, *Environmental Science and Pollution Research*, Vol. 30, No. 2, 3453–3466. doi:10.1007/s11356-022-22341-0.
34. Can, M., Ahmed, Z., Ahmad, M., and Oluc, I. (2023). Economic Progress in Emerging Countries: The Roles of Diversification of Import and Export Products and Energy Consumption, *Environment, Development and Sustainability*, Vol. 26, No. 7, 18207–18229. doi:10.1007/s10668-023-03386-8.
35. Becker, R. A. (2005). Air Pollution Abatement Costs under the Clean Air Act: Evidence from the Pace Survey, *Journal of Environmental Economics and Management*, Vol. 50, No. 1, 144–169. doi:10.1016/j.jeem.2004.09.001.
36. OECD. (2018). Green Growth Indicators, from <https://www.oecd.org/greengrowth/green-growth-indicators>.
37. Lundquist, S. (2021). Explaining Events of Strong Decoupling from CO2 and NOx Emissions in the OECD 1994–2016, *Science of The Total Environment*, Vol. 793, 148390. doi:10.1016/j.scitotenv.2021.148390.
38. van Ledden, A., Can, M., and Brusselaers, J. (2024). Toward a Greener Future: Investigating the Environmental Quality of Non-Green Trading in OECD Countries, *Ekonomikalia Journal of Economics*, Vol. 2, No. 1, 15–28. doi:10.60084/eje.v2i1.149.
39. Kahuthu, A. (2006). Economic Growth and Environmental Degradation in a Global Context, *Environment, Development and Sustainability*, Vol. 8, No. 1, 55–68. doi:10.1007/s10668-005-0785-3.
40. Ray, S., and Hardi, I. (2024). Refining ESG Disclosure's Role in Corporate Economic, Environmental, and Social Sustainability Performance, *Indatu Journal of Management and Accounting*, Vol. 2, No. 1, 1–8. doi:10.60084/ijma.v2i1.144.
41. Can, B., and Can, M. (2022). Examining the Relationship Between Knowledge and Well-Being as Values of a Society: An Empirical Analysis for Turkey, E. Alaverdov; M. W. Bari (Eds.), *Regulating Human Rights, Social Security, and Socio-Economic Structures in a Global Perspective*, IGI Global, 211–226. doi:10.4018/978-1-6684-4620-1.ch013.
42. Hatfield-Dodds, S., Schandl, H., Adams, P. D., Baynes, T. M., Brinsmead, T. S., Bryan, B. A., Chiew, F. H. S., Graham, P. W., Grundy, M., Harwood, T., McCallum, R., McCrea, R., McKellar, L. E., Newth, D., Nolan, M., Prosser, I., and Wonhas, A. (2015). Australia Is 'Free to Choose' Economic Growth and Falling Environmental Pressures, *Nature*, Vol. 527, No. 7576, 49–53. doi:10.1038/nature16065.
43. Buysse, J., Can, M., and Gozgor, G. (2018). Globalisation Outcomes and the Real Output in the Sub-Saharan Africa Lics: A Cointegration Analysis, *Economic Research-Ekonomska Istraživanja*, Vol. 31, No. 1, 338–351. doi:10.1080/1331677X.2018.1426471.
44. Can, M., Oluc, I., Sturm, B., Guzel, I., Gavurova, B., and Popp, J. (2022). Nexus Between Trading Non-Green Products and Environment: Introducing Non-Green Trade Openness Index, *Frontiers in Environmental Science*, Vol. 10. doi:10.3389/fenvs.2022.950453.
45. Thompson, P., and Strohm, L. A. (1996). Trade and Environmental Quality: A Review of the Evidence, *The Journal of Environment & Development*, Vol. 5, No. 4, 363–388. doi:10.1177/107049659600500401.
46. Paramati, S. R., Mo, D., and Huang, R. (2021). The Role of Financial Deepening and Green Technology on Carbon Emissions: Evidence from Major OECD Economies, *Finance Research Letters*, Vol. 41, 101794. doi:10.1016/j.frl.2020.101794.
47. Fay, M. (2012). *Inclusive Green Growth: The Pathway to Sustainable Development*, World Bank Publications.
48. Georgeson, L., Maslin, M., and Poessinouw, M. (2017). The Global Green Economy: A Review of Concepts, Definitions, Measurement Methodologies and Their Interactions, *Geo: Geography and Environment*, Vol. 4, No. 1. doi:10.1002/geo2.36.
49. Alvi, S., Ahmad, I., and Rehman, A. (2023). Trade of Environmental versus Non-environmental Goods and Carbon Emissions in High and Middle-Income Countries, *Environmental Science and Pollution Research*, Vol. 30, No. 24, 65283–65295. doi:10.1007/s11356-023-26972-9.
50. Can, M., Ben Jebli, M., and Brusselaers, J. (2021). Exploring the Impact of Trading Green Products on the Environment: Introducing the Green Openness Index, *Munich Personal RePEc Archive*.
51. Can, M., Ben Jebli, M., and Brusselaers, J. (2022). Can Green Trade Save the Environment? Introducing the Green (Trade) Openness Index, *Environmental Science and Pollution Research*, Vol. 29, No. 29, 44091–44102. doi:10.1007/s11356-022-18920-w.
52. Bhardwaj, A. K., Garg, A., Ram, S., Gajpal, Y., and Zheng, C. (2020). Research Trends in Green Product for Environment: A Bibliometric Perspective, *International Journal of Environmental Research and Public Health*, Vol. 17, No. 22, 8469. doi:10.3390/ijerph17228469.
53. Du, K., Li, P., and Yan, Z. (2019). Do Green Technology Innovations Contribute to Carbon Dioxide Emission Reduction? Empirical Evidence from Patent Data, *Technological Forecasting and Social Change*, Vol. 146, 297–303. doi:10.1016/j.techfore.2019.06.010.
54. Li, J., Dong, K., Dong, X., and Shahbaz, M. (2022). How Green Trade Influences Pollution Emissions in China: A Provincial

- Perspective, *Energy Economics*, Vol. 115, 106330. doi:10.1016/j.eneco.2022.106330.
55. Li, Z., Xu, N., and Yuan, J. (2015). New Evidence on Trade-Environment Linkage via Air Visibility, *Economics Letters*, Vol. 128, 72–74. doi:10.1016/j.econlet.2015.01.014.
56. Antweiler, W., Copeland, B. R., and Taylor, M. S. (2001). Is Free Trade Good for the Environment?, *American Economic Review*, Vol. 91, No. 4, 877–908. doi:10.1257/aer.91.4.877.
57. Yasmeen, R., Li, Y., and Hafeez, M. (2019). Tracing the Trade–Pollution Nexus in Global Value Chains: Evidence from Air Pollution Indicators, *Environmental Science and Pollution Research*, Vol. 26, No. 5, 5221–5233. doi:10.1007/s11356-018-3956-0.
58. Liu, H., Lei, H., and Zhou, Y. (2022). How Does Green Trade Affect the Environment? Evidence from China, *Journal of Economic Analysis*. doi:10.58567/jea01010001.
59. Zugravu-Soilita, N. (2018). The Impact of Trade in Environmental Goods on Pollution: What Are We Learning from the Transition Economies' Experience?, *Environmental Economics and Policy Studies*, Vol. 20, No. 4, 785–827. doi:10.1007/s10018-018-0215-z.
60. Kanemoto, K., Moran, D., Lenzen, M., and Geschke, A. (2014). International Trade Undermines National Emission Reduction Targets: New Evidence from Air Pollution, *Global Environmental Change*, Vol. 24, 52–59. doi:10.1016/j.gloenvcha.2013.09.008.
61. Grossman, G. M., and Krueger, A. B. (1993). Environmental Impacts of a North American Free Trade Agreement, *The Mexico-US Free Trade Agreement*, Vol. 11, No. 2, 13.
62. De Alwis, J. M. D. D. J. (2015). Environmental Consequence of Trade Openness for Environmental Goods, *Sri Lankan Journal of Agricultural Economics*, Vol. 16, No. 1, 79. doi:10.4038/sjae.v16i1.4606.
63. Zugravu-Soilita, N. (2019). Trade in Environmental Goods and Air Pollution: A Mediation Analysis to Estimate Total, Direct and Indirect Effects, *Environmental and Resource Economics*, Vol. 74, No. 3, 1125–1162. doi:10.1007/s10640-019-00363-6.
64. Neagu, O., Porumbăcean, T., and Anghelina, A. M. (2023). Does Financial Development, Globalisation and Institutional Quality Drive the Income Convergence in the Central and Eastern European Union Countries? *Studia Universitatis „Vasile Goldis” Arad-Economics Series*, Vol. 33, No. 1, 88–108.
65. Can, M., Ahmed, Z., Mercan, M., and Kalugina, O. A. (2021). The Role of Trading Environment-Friendly Goods in Environmental Sustainability: Does Green Openness Matter for OECD Countries?, *Journal of Environmental Management*, Vol. 295, 113038. doi:10.1016/j.jenvman.2021.113038.
66. Westerlund, J. (2008). Panel Cointegration Tests of the Fisher Effect, *Journal of Applied Econometrics*, Vol. 23, No. 2, 193–233. doi:10.1002/jae.967.
67. Lee, M. T., Raschke, R. L., and Krishen, A. S. (2022). Signaling Green! Firm ESG Signals in an Interconnected Environment That Promote Brand Valuation, *Journal of Business Research*, Vol. 138, 1–11. doi:10.1016/j.jbusres.2021.08.061.
68. Ahmad, M., Ahmed, Z., Bai, Y., Qiao, G., Popp, J., and Oláh, J. (2022). Financial Inclusion, Technological Innovations, and Environmental Quality: Analyzing the Role of Green Openness, *Frontiers in Environmental Science*, Vol. 10. doi:10.3389/fenvs.2022.851263.
69. Dumitrescu, E.-I., and Hurlin, C. (2012). Testing for Granger Non-causality in Heterogeneous Panels, *Economic Modelling*, Vol. 29, No. 4, 1450–1460. doi:10.1016/j.econmod.2012.02.014.
70. van Hek, S., Can, M., and Brusselsaers, J. (2024). The impact of non-green trade openness on environmental degradation in newly industrialized countries, *Ekonomikalia Journal of Economics*, Vol. 2, No. 2, 66–81. doi:10.60084/eje.v2i2.148.
71. De Hoyos, R. E., and Sarafidis, V. (2006). Testing for Cross-Sectional Dependence in Panel-Data Models, *The Stata Journal: Promoting Communications on Statistics and Stata*, Vol. 6, No. 4, 482–496. doi:10.1177/1536867X0600600403.
72. Pesaran, M. H. (2021). General Diagnostic Tests for Cross-Sectional Dependence in Panels, *Empirical Economics*, Vol. 60, No. 1, 13–50. doi:10.1007/s00181-020-01875-7.
73. Pantula, S. G., Gonzalez-Farias, G., and Fuller, W. A. (1994). A Comparison of Unit-Root Test Criteria, *Journal of Business & Economic Statistics*, Vol. 12, No. 4, 449–459. doi:10.1080/07350015.1994.10524567.
74. Pesaran, M. H. (2012). On the Interpretation of Panel Unit Root Tests, *Economics Letters*, Vol. 116, No. 3, 545–546. doi:10.1016/j.econlet.2012.04.049.
75. Pesaran, M. H. (2007). A Simple Panel Unit Root Test in the Presence of Cross-Section Dependence, *Journal of Applied Econometrics*, Vol. 22, No. 2, 265–312. doi:10.1002/jae.951.
76. Choi, I. (2015). Panel Cointegration, *The Oxford Handbook of Panel Data*, Oxford University Press, 46–75. doi:10.1093/oxfordhb/9780199940042.013.0002.
77. Machado, J. A. F., and Santos Silva, J. M. C. (2019). Quantiles via Moments, *Journal of Econometrics*, Vol. 213, No. 1, 145–173. doi:10.1016/j.jeconom.2019.04.009.
78. Ogbeifun, L., and Shobande, O. A. (2022). A Reevaluation of Human Capital Accumulation and Economic Growth in OECD, *Journal of Public Affairs*, Vol. 22, No. 4. doi:10.1002/pa.2602.
79. Twerefou, D. K., Akpalu, W., and Mensah, A. C. E. (2019). Trade-Induced Environmental Quality: The Role of Factor Endowment and Environmental Regulation in Africa, *Climate and Development*, Vol. 11, No. 9, 786–798. doi:10.1080/17565529.2018.1562868.
80. de Melo, J., and Solleder, J.-M. (2020). Barriers to Trade in Environmental Goods: How Important They Are and What Should Developing Countries Expect from Their Removal, *World Development*, Vol. 130, 104910. doi:10.1016/j.worlddev.2020.104910.
81. Schumacher, R. (2013). Deconstructing the Theory of Comparative Advantage, *World Social and Economic Review*, Vol. 2, 83.
82. Uzun, F. V., and Keles, O. (2012). The Effects of Nature Education Project on the Environmental Awareness and Behavior, *Procedia - Social and Behavioral Sciences*, Vol. 46, 2912–2916. doi:10.1016/j.sbspro.2012.05.588.
83. McGinty, M., and de Vries, F. P. (2009). Technology Diffusion, Product Differentiation and Environmental Subsidies, *The B.E. Journal of Economic Analysis & Policy*, Vol. 9, No. 1. doi:10.2202/1935-1682.2099.
84. Zolfagharinia, H., Zangiabadi, M., and Hafezi, M. (2023). How Much Is Enough? Government Subsidies in Supporting Green Product Development, *European Journal of Operational Research*, Vol. 309, No. 3, 1316–1333. doi:10.1016/j.ejor.2023.02.011.
85. Sauvage, J. (2014). The Stringency of Environmental Regulations and Trade in Environmental Goods, *OECD Trade and Environment Working Papers*, Vol. 03. doi:10.1787/18166881.