The Relationship Between Environmental Quality, Carbon Gas Emissions and International Trade: Perspectives for Sustainable Development

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Abstract

This study examines the environmental quality index, CO ^{2} emissions from the manufacturing and construction industry, and international trade. This research uses quantitative methods with an autoregressive distributed lag (ARDL) model. We found that environmental quality is an environmental condition that provides optimal power to support human survival in an area. A quality environment includes aspects such as water quality, air quality, soil quality, and land cover quality. Rapid economic growth in recent decades has increased pressure on the environment through various human activities, including manufacturing, construction, and international trade. The main objective of measuring the environmental quality index is to provide an overview of the current state of the local environment and provide a basis for making sustainable decisions regarding environmental protection.

Keywords : Environmental Quality, Emissions, International Trade, Sustainable Development

JEL Classification: C32,L83,O53

Received: August 6,2023 Accepted: September 1,2023
DOI : 10.54204/TAJI/Vol1012023007

Introduction

Environmental quality is an important aspect in maintaining the balance of the earth's ecosystem which has received world attention (Sulisnaningrum, Mutmainah, Bawono, & Drean, 2023). In recent decades, rapid economic growth has increased pressure on the environment from various human activities such as manufacturing, construction, and international trade. Increasing greenhouse gas emissions, especially from the industrial sector, is one of the biggest challenges in maintaining environmental quality (Boori, Choudhary, Paringer, & Kupriyanov, 2021).

The environmental quality index variable is an overall measure for assessing the environmental status of a region or country. These indicators cover a variety of factors, including air, water and soil quality, biodiversity, and the impact of human activities on natural ecosystems. The main aim of this index is to provide an overview of the local environmental situation and provide a basis for sustainable environmental protection decisions (Ahmad, Ahmed, Majeed, & Huang, 2021).

Variable CO2 emissions from manufacturing and construction are mainly related to production processes, transportation and use of fossil energy resources. On the other hand, international trade can affect environmental quality in many ways, including the use of natural resources, transportation of goods, and the transfer of technology and environmentally friendly practices between countries (Lin & Xu, 2020). Therefore, the relationship between the variable (environmental quality index) and these variables is as follows. Analyzing these relationships provides effective guidance for reducing greenhouse gas emissions, increasing resource efficiency, encouraging sustainable trade practices, and achieving sustainable economic, social, and environmental development. It is hoped that this will enable the identification of strategies and policies.

Literature Review

The Kuznets environmental curve assumes that sustainable economic growth can be achieved in transition countries when per capita income reaches a certain threshold. Trade openness, through a combination of scale, composition and technological effectiveness, is also one of the main factors that helps countries in transition reduce carbon emissions and at the same time achieve economic growth (Cheon Yu, 2019) With a sustainable environmental governance model and emphasizing a strong legal structure and clarity of implementation. GDP does not have a significant impact on CO2 emissions, so there is an opportunity to switch to a sustainable economic growth model (Afjal, 2023).

Increasing openness to foreign trade reduces CO2 emissions in sectors that are less CO2 intensive. Factors such as the intensity of economic activity, workload levels, unique technological innovations, and GDP per capita have a significant impact on industrial sector CO2 emissions (Salim, 2024). Carbon inequality in international trade can be divided into three categories, victims of absolute carbon inequality, relative carbon inequality, and beneficiaries of absolute carbon inequality. Carbon inequality occurs between developed and developing countries as well as between developing countries in bilateral trade (Hao Chen, 2024).

Carbon emissions disclosure in Indonesia continues to increase, with slight increases from year to year, depending on the company's environmental performance. Apart from that, leverage has a negative effect and institutional ownership has a small effect on carbon emissions disclosure. This study confirms the moderating role of environmental performance variables in reversing the influence of independent factors (Wahyuningrum, 2024). The use of green technologies and renewable energy improves the environment, but ecological damage is exacerbated by export diversification, tax decentralization, and economic growth. BRICS countries need to be careful in implementing export diversification and tax decentralization programs (Ngepah, 2023).

Government integrity plays an important role in realizing a more efficient and environmentally friendly production process. The results obtained produce several policy recommendations that should be considered when developing energy policy instruments to reduce environmental degradation (Syed Abdul Rehman Khan, 2022). The spatial and temporal evolution trends of ECTN features are investigated through complex network analysis . These results show that carbon leakage between states is getting worse. The small nature of ECTN is becoming increasingly clear. The distribution of countries that have a major impact on carbon migration has shifted from north to south and towards the central region (Dong, 2023).

Renewable energy, open trade and innovation can reduce emissions, while global tourism increases environmental degradation. These results have important policy implications for the implementation of trade openness measures to improve environmental quality. Innovations that improve environmental quality in both groups could be a major discovery for the authorities. The results show that renewable energy and technological innovation are very important for sustainable development (Duyen Thi, 2023). The growth in construction supply worldwide is causing a lot of material consumption and environmental impacts. Future impacts will depend on the level and extent of socio-economic development as well as raw material sourcing and use strategies. Greenhouse gas (GHG) emissions related to materials for residential and commercial buildings can be evaluated based on their mitigation potential in 26 world regions in 2060 (Zhong, Hu, Deetman, Steubing, & Lin, 2021).

Economic principles provide a clear answer: reduction What is the most economically effective way to reduce greenhouse gases. This response can be achieved through a Pigouvian tax, for example a carbon tax of the amount where the tax rate is the marginal benefit from

reducing emissions or, equivalently to the monetary loss due to emissions, over one ton of carbon dioxide (CO2) (Gillingham & Stock 2018).

Industrial activities are one source of CO2 emissions. Kendal Regency is a region that functions as one of the centers of industrial activity in Central Java province. The aim of this research is to determine the distribution of CO2 emission sources from the industrial sector and analyze the factors that influence the growth of these emissions as a basis for preparing policy implications for the spatial planning of industrial activities in Kendal Regency based on low carbon cities. Concept analysis was carried out on 9 large-scale industrial activities spread across 3 sub-districts in Kendal Regency, namely Kaliwungu, Boja and Kangkung sub-districts, using the IPCC (Inter Governmental Panel of Experts on Climate Change) calculation method. The results of the analysis of the production intensity level of CO2 emissions from industrial activities show that PT. Sinar Bahari Agung in Kangkung Regency produces the highest CO2 emissions. Meanwhile, the results of the analysis of potential growth in CO2 emissions show that until 2031, the growth rate of CO2 emissions in the Kendal Regency industrial sector will continue to increase (Labiba & Pradoto, 2018).

Emissions are one of the many harmful environmental aspects that can impact overall change in the world. The fuel oil used in transportation infrastructure is known to be the most important in producing high emission intensity for large cities such as Jakarta. The real impact is that many people are affected by diseases due to air pollution. The use of land or green cities, including what is referred to as "urban forests" or open spaces, will bring new hope in the future as part of cities that aim to reduce air pollution and exhaust gases. The analysis method is carried out by collecting and analyzing secondary data. Involves the production of carbon dioxide from certain urban activities such as using electricity and fuel in Jakarta. The need for transportation and electrical energy are the basic needs of urban communities, but have the greatest impact on carbon dioxide production. The availability of open space and quality energy efficiency policies must be one of the central and regional government agendas as well as the main solution to overcome these problems (Edyanto, 2014).

This shift in focus was driven by increasing evidence that transacting firms differ significantly from nontransacting firms, and that these differences have important consequences for the assessment of trade profits and their allocation among various factors of production. Some of these consequences complement traditional ideas; the others are new. Although international trade theory has recently made great progress in explaining trade patterns and productivity growth by incorporating the behavior of heterogeneous firms, much remains to be explained (Bernard et al., 2007)

International trade is an important strategic activity in the development process of a developing economy. International specialization means that different countries in the world specialize in the production of different types of goods. Develop and implement trade policies including issues such as tariffs, incentives, quotas, taxes, customs and administration, subsidies, rules of origin, public procurement regimes, aid and investment, export promotion, trade facilitation and diversification. Therefore, the role of foreign trade in driving economic development is well known. Therefore, foreign trade planning cannot be separated from the overall development strategy. The disadvantage of international trade is that the welfare of people in countries producing goods and services is sometimes ignored in favor of profit. In conclusion, it can be said that international trade leads to economic growth provided that policy measures and economic infrastructure are adjusted adequately to address the impact of changing fiscal and societal scenarios (Vijayasri, 2013).

The Swedish National Council for Housing, Construction and Planning provided data on temperature, relative humidity, air exchange rate, NO2 concentration, formaldehyde and TVOC measured in 157 single-family houses and 148 apartments in residential areas in

Sweden. As found in previous Scandinavian research, the majority of residences do not meet the ventilation guidelines of Swedish building regulations. The air renewal rate in apartments is much higher than that of single-family homes. NO2, formaldehyde and TVOC concentrations are relatively low; The median value is lower than the recommended indoor air quality value of. NO2 concentrations in single-family homes are much lower than in apartments. This observation, along with the lower ventilation rates measured in single-family homes, supports previous findings that ventilation with outdoor air is one of the main sources of indoor NO2 production. The significant positive correlation between NO2 concentration and air exchange rate also supports this conclusion (Langer & Beko, 2013). Usually, many kinds of dangerous pollutants accumulate in subway stations. To control indoor air quality (IAQ) at metro stations, a control strategy based on a prediction model is used that is not influenced by temperature due to seasonal changes (Kim, SankaraRao, Kang, Kim, & Yoo, 2012)

The quality of the environment is important in every aspect of life, but community actions aimed at improving the economy often ignore the negative impacts they cause (Padilla-Rivera, Russo-Garrido, & Merveille, 2020). Industry sensitivity, independent commissioners, dual mandate, size of the board of commissioners, company size and profitability influence the quality of environmental disclosure. Meanwhile, the variables of media coverage, gender diversity, and institutional ownership have no effect on the quality of environmental disclosure. Environmental quality can be influenced by various factors including the utilization of natural resources, transportation of goods, technology transfer, and eco-friendly initiatives among nations (Ikram, Ferasso, Sroufe, & Zhang, 2021). The following hypotheses are proposed:

H1: Enhanced environmental quality in a country correlates with reduced carbon emissions.

H2: The interplay between environmental quality and carbon dioxide emissions is moderated by the extent of international trade.

Examining these dynamics offers valuable insights for diminishing greenhouse gas emissions, augmenting resource efficiency, promoting sustainable business operations, and fostering sustainable development across economic, social, and environmental spheres. This study delves into indicators of environmental quality, CO2 emissions stemming from the manufacturing and construction industries, and the impact of international trade.

Research Methods

This study examines the environmental quality index, CO^2 emissions from the manufacturing and construction industry, and international trade. This research uses quantitative methods with an autoregressive distributed lag (ARDL) model with the following equation :

$KL = \beta0 + \beta1Eit + \beta2Co2 + et$

$CO2 = \beta0 + \beta1IKLH1 + \beta2Eit2 + et$

$PI = \beta0 + \beta1IKLH2 + \beta2Eit3 + et$

Information :

KL = Environmental Quality Index (%)

CO2 = Carbon dioxide emissions

PI = International Trade

β = Constant

e = Error term

t = Time Period

This research uses a research period from 1999 to 2020. The descriptive variables are taken from the variables used as indicators which are presented in the following 4 variables.

Table 1. Variable Description

Variable	Description	Source	Unit of Analysis
KL	Environmental quality refers to the conditions and characteristics of the natural environment that can affect human health, ecosystem sustainability, and the welfare of plants and animals. The definition of environmental quality often includes various aspects, such as the cleanliness of air, water, soil and biodiversity. Measuring and monitoring environmental quality is very important to detect changes that occur and take necessary actions to maintain and improve environmental quality.	BPS	Percent
CO 2	Carbon gas emissions are the release of carbon-containing gases into the atmosphere. This carbon gas comes from various natural and anthropogenic sources (due to human activities). Common carbon gases include carbon dioxide (CO2), methane (CH4), nitrogen oxide (N2O), and other gases such as carbon monoxide (CO) and carbon tetrachloride (CCl4). Carbon gas emissions from these sources cause an increase in the greenhouse effect, contribute to global climate change, and have the potential to affect climate and environmental balance, including global temperature changes, extreme weather events, and sea level rise. Therefore, reducing carbon gas emissions is the main focus of climate change mitigation efforts.	World Bank	Percent
PI	Exchange of goods and services between two or more countries through cross-border trade routes. This includes the import and export of goods and services between the countries involved. International trade is a major driver of global economic growth and one of the key elements of the modern economy. International trade has a significant impact on economic growth, employment, income distribution, and economic stability at the global and national levels.	World Bank	Percent

Results and Discussion

Before carrying out further testing, the first variable that must be carried out is to test the stationarity of the data. This is done to find out whether the data is stationary or not. The test results are presented in the following table.

Table 2. Root Test Results

Variables	Root Unit	Statistics for the ADF	Probability	Information
Co2	Levels	-1.778235	0.3801	Not stationary
	First diff	-6.049276	0.0001	Stationary
KL	Levels	-0.279416	0.9120	Not stationary
	First diff	-5.056524	0.0008	Stationary
PI	Levels	-2.154822	0.2271	Not stationary
	First diff	-5.398276	0.0003	Stationary

Environmental quality data is not stationary because the statistical ADF value (-1.778235) is greater than the critical value (0.3801) at the 5% significance level. First difference:

Environmental quality data is determined after the first difference because the statistical ADF value (-6.049276) is smaller than the critical value of the 5% significance level (0.0001). Carbon gas emission data is not stationary because the ADF statistic (-0.279416) is greater than the critical value at the 5% significance level. (0.9120).First difference: Because the statistical ADF value (-5.056524) is smaller than the critical value at the 5% significance level (0.0008), the carbon gas emission data becomes stationary after the first differentiation. International trade data is not stationary because the statistical ADF value (-2.154822) is greater than the critical value of 5%. The significance level is: (0.2271). First difference: International trade data is determined after the first difference because the statistical ADF value (-5.398276) is smaller than the critical value of the 5% significance level (0.0003).

Table 3. Cointegration Test

Hypothesized No. of CE(s)	Eigenvalues	Trace Statistics	0.05Critical Value	Prob.**
None *	0.679010	3.111.827	2.979.707	0.0350
At most 1	333973	8.391.341	1.549.471	0.4245
At most 2	0.013056	0.262842	3.841.466	0.6082

The results of the cointegration test show that there is the best long-term relationship between environmental quality, carbon gas emissions, and international trade.

Table 4. ARDL Estimation Result

Variable	coefficient	Std. Error	t-Statistics	Prob.*
CO2(-1)	-0.590227	0.364679	-1.618.486	0.1809
CO2(-2)	-0.439624	0.403634	-1.089.164	0.3373
CO2(-3)	-0.217255	0.227457	-0.955148	0.3936
CO2(-4)	-0.271713	0.229072	-1.186.150	0.3012
KL	44480.69	42835.05	1.038.418	0.3577
KL(-1)	19204.95	55869.82	0.343745	0.7483
KL(-2)	5.628.009	49348.42	0.114046	0.9147
KL(-3)	-17226.26	46645.10	-0.369305	0.7306
KL(-4)	89733.43	34848.58	2.574.952	0.0617
PI	-1.537.645	1.403.528	-1.095.557	0.3348
PI(-1)	4.429.435	1.623.850	0.272774	0.7985
PI(-2)	1.083.116	1.099.997	0.984654	0.3805
PI(-3)	1.032.117	1.430.468	0.721524	0.5105
C	-5670094.	2079312.	-2.726.909	0.0526

This shows that the increase in carbon gas emissions in the previous period will reduce the quality of the environment in the current period. CO2(-2), CO2(-3), CO2(-4): The coefficients for the variables CO2(-2), CO2(-3), and CO2(-4) are invalid Important. This shows that carbon gas emissions in the last two, three and four periods do not have a significant impact on environmental quality in the current period. KL: International trade has a positive and significant impact on environmental quality. This shows that increasing international trade improves environmental quality. KL(-1), KL(-2), KL(-3). The coefficients for the variables KL(-1), KL(-2), and KL(-3) are not significant. This shows that international trade in the previous period did not have a significant impact on environmental quality in the current period. KL(-4) International trade has had a positive and significant impact on environmental quality over the last four periods. This shows that the increase in international trade in the last four periods has improved the quality of the environment in the current period. PI: The producer price index does not have a significant influence on environmental quality.

Table 5. Cointegration Of Bound Test On ARDL

Variables	Coefficient	Std. Error	t-Statistics	Prob.
KL	56304.48	8.759.768	6.427.622	0.0030
PI	4.051.627	7.378.106	0.549142	0.6121
C	-2251092.	363054.0	-6.200.433	0.0034

Coefficient interpretation: KL: International trade has a positive and significant influence on environmental quality in the long term. PI: The producer price index does not have a significant long-term effect on environmental quality. C: This constant shows the long-term value of environmental quality if all independent variables are equal to zero.

Table 6. Autocorrelation Test

variable	Coefficient	Std. Error	t-Statistics	Prob.
C	61400.95	799211.3	0.076827	0.9396
KL	-1.441.729	16350.61	-0.088176	0.9307
PI	0.806485	7.739.439	0.104205	0.9182
RESID(-1)	0.081333	0.248015	0.327937	0.7467

Autocorrelation coefficient (residual (-1)): 0.081333 T-statistic value: 0.327937 Probability value: 0.7467 Conclusion: Probability value (0.7467) This rejects the hypothesis H0 and the model shows that there is not enough evidence to concluded that there was no autocorrelation. Coefficient Interpretation: C: Constant shows the average value of environmental quality. KL: International trade has a negative and significant impact on environmental quality. PI : The producer price index has a positive and significant effect on environmental quality. RESID(-1): The autocorrelation value shows that there is a relationship between the residual value of the previous period and the current period.

Table 7. Heteroscedasticity Test

F-statistic	2.454.198	Prob. F(2.19)	0.1127
Obs*R-squared	4.516.603	Prob. Chi-Square(2)	0.1045
Scaled explained SS	1.842.190	Prob. Chi-Square(2)	0.3981

The probability value (0.1127) is above the 5% significance level. This shows that there is not enough evidence to reject hypothesis H1 and conclude that the model is not heteroscedastic. Other tests: Obs*R squared test: The probability value (0.1045) is above the 5% significance level. This shows that there is not enough evidence to reject hypothesis H1 and conclude that the model is not heteroscedastic. SS Scale Test Description: The probability value (0.3981) is above the 5% significance level. This shows that there is not enough evidence to reject hypothesis H1 and conclude that the model is not heteroscedastic.
Conclusion: Based on the results of the F statistic, Obs*R squared test, and SS test of scale explanation, it can be concluded that the model is free from heteroscedasticity.

Table 8. ARDL Using Robust Estimator

Variables	Coefficient	Std. Error	t-Statistics	Prob.
C	-3309450.	737854.3	-4.485.234	0.0003
KL	84274.19	14515.06	5.805.981	0.0000
PI	-1.709.744	5.867.578	-2.913.884	0.0089

The F-statistic (5.805981) is above the critical upper limit at all levels of significance. This shows that there is sufficient evidence to reject the H0 hypothesis and conclude that there is a long-term relationship between environmental quality, carbon gas emissions, and international trade.

Table 9. Short Term Equations In ARDL

Variables	Coefficient	Std. Error	t-Statistics	Prob.
D(KL)	91639.81	22179.14	4.131.801	0.0007
D(PI)	-3.170.134	7.285.052	-4.351.559	0.0004
ECT(-1)	-1.067.751	0.217565	-4.907.726	0.0001
C	-4.967.987	55915.33	-0.008885	0.9930

Short-term relationship: Changes in international trade (D(KL)) have a positive and significant impact on environmental quality. This shows that increasing international trade improves environmental quality in the short term. Changes in the producer price index (D(PI)) have a negative and significant influence on environmental quality. This shows that an increase in the producer price index in the short term causes a decrease in environmental quality. The error correction term (ECT(-1)) indicates how quickly environmental quality adapts to long-term imbalances. The negative and significant value of the ECT(-1) coefficient indicates convergence towards long-term balance.

Table 10. Long Run Equations In ARDL

Variables	Coefficient	Std. Error	t-Statistics	Prob.
KL	84274.19	15374.16	5.481.547	0.0000
PI	-1.709.744	7.163.901	-2.386.611	0.0276
C	-3309450.	758502.7	-4.363.135	0.0003

Coefficient Interpretation: KL: The coefficient of 84,274.19 indicates that for every increase in one unit of international trade (KL), the quality of the environment (y) increases by 84,274.19 units in the long term. PI: The coefficient -17.09744 shows that for every one unit increase in the producer price index (PI), environmental quality (y) decreases by 17.09744 units in the long term. C: The constant -3,309,450 indicates the long-term average value of environmental quality (y) when all independent variables are equal to zero.

Conclusion

Environmental quality is an environmental condition that provides optimal power to support human survival in an area. A quality environment includes aspects such as water quality, air quality, soil quality, and land cover quality. Rapid economic growth in recent decades has increased pressure on the environment through various human activities, including manufacturing, construction, and international trade. The main objective of measuring the environmental quality index is to provide an overview of the current state of the local environment and provide a basis for making sustainable decisions regarding environmental protection.

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