Environmental Goods Trade and Environmental Sustainability: Exploration of the Effect of Greenhouse Emissions in Europe

[1]Dr. Usman, Jabir Muhammed., [1]Dr. Agunbiade, Olabode., [2]Dr. Ahmed, Ibrahim

[1]Department of Economics, Mewar International University, Masaka, Nasarawa State

[2]National Examinations Council, Nigeria

DOI: https://dx.doi.org/10.47772/IJRISS.2025.910000797

Received: 02 November 2025; Accepted: 10 November 2025; Published: 24 November 2025

ABSTRACT

This study examines the influence of trade in environmental goods on environmental sustainability, with a particular emphasis on the impact of greenhouse gas emissions in Europe. Utilising annual data from 59 European countries over the period 1994–2024, the research incorporates environmental sustainability indicators sourced from the World Development Indicators (WDI, 2022) and trade data from the International Monetary Fund (IMF, 2024). The analysis employs second-generation econometric techniques to address cross-sectional dependence and heterogeneity, including Pesaran's (2004, 2015) tests, Westerlund's (2007) cointegration approach, and the Augmented Anderson-Hsiao (AAH) estimator as proposed by Chudik and Pesaran (2022). Empirical findings indicate a significant long-term cointegration between trade in environmental goods and greenhouse gas emissions. Specifically, exports of environmental goods and total trade in these goods contribute to the reduction of emissions, whereas energy consumption continues to be a primary driver of environmental degradation. Additionally, the import of environmental goods shows a weak but negative relationship with greenhouse emissions, suggesting that imported environmental technologies may enhance production efficiency. The study further concludes that trade in environmental goods is pivotal in achieving environmental sustainability across European economies by fostering cleaner production and innovation-driven growth. Consequently, policies that promote the expansion of green trade, reduce trade barriers on environmental goods, and encourage the use of renewable energy are essential to bolstering Europe's environmental resilience. Moreover, advancing research and development in clean technologies, harmonising regional carbon standards, and incentivizing sustainable production practices will facilitate Europe's transition toward a low-carbon economy.

Keywords: Environmental goods trade, environmental sustainability, greenhouse gas emissions, Europe, panel econometrics, renewable energy

INTRODUCTION

The growing global awareness of environmental issues has placed sustainability at the forefront of policy, research, and innovation. As the Brundtland Commission stated in 1987, sustainability emphasizes the need for a balance between economic growth, social inclusion, and environmental protection. With the increasing challenges of climate change, deforestation, and biodiversity loss, implementing sustainable practices has become a crucial global necessity. The pursuit of environmental sustainability is now a significant concern worldwide, as we face the pressing issues of climate change, resource depletion, and environmental degradation (IPCC, 2020; UNEP, 2020). The extensive effects of environmental degradation threaten human health, economic progress, and social well-being (WHO, 2018; WCED, 1987).

In Europe, the issue of environmental sustainability has become crucial, driven by its challenges as highlighted by the European Environment Agency in 2020. The European Union (EU) has taken a leading role in global initiatives to foster environmental sustainability, implementing ambitious policies and targets aimed at cutting greenhouse gas emissions, transitioning to a low-carbon economy, and encouraging sustainable development (European Commission, 2020). Environmental sustainability covers a wide array of dimensions, including environmental, economic, and social factors (WCED, 1987). The growing demand for environmental goods stems from several converging factors, including the EU's environmental policy framework, particularly the CEF and CEP; a rising consumer preference for greener products; advancements in technology; and global trade agreements like the EGA under the WTO.

However, the swift growth of environmental goods trade in Europe brings up significant concerns regarding its environmental impact, such as the carbon footprint associated with production and transportation, resource depletion and extraction, environmental degradation in the countries of origin, and issues like green washing or environmental dumping. Europe is at the forefront of global environmental sustainability, driven by its ambitious climate goals, initiatives like the European Green Deal, and active involvement in multilateral trade agreements. Trading in environmental goods offers a crucial pathway to cleaner technologies that facilitate the transition to a low-carbon economy. Nevertheless, challenges persist due to various trade barriers, unequal access to technology, and regulatory complexities, despite Europe's prominent position in this arena (Usman et al., 2025).

The global trade in EGs has seen substantial growth, fueled by rising demand for sustainable products, advancements in technology, and the liberalization of trade (OECD, 2019). However, the trade environment is complicated by tariff and non-tariff barriers, differing regulations, information gaps, and challenges related to intellectual property rights (Kalamova et al., 2019). These obstacles limit the potential of EG trade to enhance environmental sustainability and drive economic development. Considering the growing significance of environmental goods trade in achieving sustainable development, concerns about its environmental impact have also increased (OECD, 2019; UNEP, 2020). While trading in environmental goods can help lower greenhouse gas emissions, enhance resource efficiency, and encourage sustainable consumption patterns, it also brings notable environmental challenges. These include the carbon footprint associated with production and transportation, resource depletion, and environmental degradation in the countries where these goods originate (Kalamova et al., 2019; Zhou et al., 2020).

Over the years, European countries have introduced various policies to address the imbalances in environmental goods trade and enhance sustainability. These include efforts to reduce or eliminate tariffs on environmental goods to boost trade and promote sustainability, as well as initiatives aimed at harmonizing environmental regulations and standards across Europe to facilitate trade while ensuring environmental protection, greenhouse procurement which seeks to motivate governments and businesses to purchase environmentally friendly goods and services among others (Usman et al., 2025).

The relationship between environmental goods trade and environmental sustainability, particularly in European countries, has garnered significant attention from researchers, stakeholders, and policymakers. Studies by Kalamova et al. (2019), Zhou et al. (2020), Ekins et al. (2019), and Mayer et al. (2019) indicate that environmental goods trade positively influences the reduction of greenhouse gas emissions in Europe. In contrast, research by Alola et al. (2019b), Charfeddine (2017), and Dogan et al. (2019) suggests a negative impact on environmental sustainability, as noted by Wang & Dong (2019) and Hassan et al. (2019). Other focused on the interaction between environmental goods trade, including works by Cosmas et al. (2019), Ali et al. (2016), Rafindadi (2016), Lin et al. (2015), and Nathaniel et al. (2020).

Despite the plethora of studies, little attention is paid to the asymmetries effect of greenhouse gas emissions in analyzing the effects of environmental goods trade shocks on environmental sustainability in Europe. Also considering the effort of enhancing trade in EGs through tariff reduction, it remains unclear how trade in EGs is vital to environmental quality. What are the transmissions medium? Are the exporting countries of EGs influenced identically as net importing countries? And given the rate of greenhouse emissions sustainability effect in Europe countries, this kind of study is necessary to provide an empirical insight on the issue.

The study is subsequently organized as follows: Section 2 presents a related literature on the relationship between EGs and environmental suitability in Europe; Section 3 presents the data description and specifies the model. The results are discussed in Section 4 whereas Section 5 entails the conclusion and recommendation based on the findings.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue X October 2025

LITERATURE REVIEW

Duodu and Mpuure (2023) investigated the impact of international trade on environmental pollution for 33 sub–Saharan African countries using the GMM estimator. The outcome shows that in total, trade boost environmental sustainability in the short and long run. The study further dis-aggregated trade into exports and import and examine their effect on the environment. The result remains the same as when overall trade was considered. The plausible reason for this result is that involving in international trade has the tendency to enhance environmental sustainability. This can be credited to the fact that foreign trade stimulate the spread of green technologies, which emerging economies accept to revamp their economic sectors which in turn mitigate the destructive effect of CO_2 pollution on the environment. Also, Ali et al. (2016) discovered that increase in trade openness has the capacity to reduce CO_2 pollution. Similarly, Iheonu (2021) find that in countries where the level of CO_2 is low, international trade supports environmental sustainability. Ma and Wang (2021) systematically examined the role of international trade for 179 countries by considering the impact of trade in goods and services on environmental pollution. Their outcome shows that international trade that concerns goods can significantly lessen pollution intensity. In the sub-Saharan Africa, the study by Okelele et al. (2022) finds that the rise in trade openness leads to a decrease of ecological footprint per capita.

Alhassan (2022) examined the impact of trade in environmental goods and environmental sustainability on production, consumption and trade based ecological footprint (comprehensive indicator of environmental degradation) in Asia. Using second generation panel time series techniques and the Augmented Anderson–Hsiao (AAH) two-step GMM estimator with a sample of Asian countries over the period 1994-2021, the findings confirm the environmental Kuznets Curve Hypothesis (EKC) in all the models. Second, the results support the pollution haven hypothesis because trade openness has significant negative impact on the ecological footprint in all the models. This implies that trade openness reduces environmental degradation and the result revealed that increase in ecological goods imports, exports and total trade reduces ecological print in Asia.

Burki and Tahir (2022) study the determinants of environmental pollution in Asian economies using panel data techniques such as pooled least squares, fixed effects, generalized least squares (GLS) and two stages least squares (2SLS). Among other variables trade openness is found to reduce environmental quality. The results illustrate that increasing energy consumption, trade openness, and financial development positively contribute to environmental degradation in ASEAN economies. The causality analysis shows a two-way causality between trade openness and financial development, and environmental degradation and trade openness from energy consumption and per capita income towards financial development from per capita income towards trade openness, and financial development towards environmental degradation. The study's results contribute to the environmental degradation literature and provide a better understanding of environmental degradation for policymakers in ASEAN economies.

Rafique et al. (2022) examine the impact of economic complexity and renewable energy on environmental sustainability including other control variables such as human capital, economic growth, export quality and trade for ten most economic complex countries. The study used the FMOLS, DOLS, and system GMM and obtained consistent results across different methods. Economic complexity, economic growth, export quality, trade and urbanization were found to be detrimental to environmental sustainability while renewable energy and human capital were found to enhance the quality of the environment. Economic complex countries have advance productive structures which will significantly hurt the environment. However, with the efficient use of technology renewable energy is employed to mitigate degradation. Also, the increase of export and trade raises the production process which worsens the quality of the environment. Can et al. (2020) investigate whether trade is important in determining environmental quality in developing countries. The outcome from the different estimators used shows that product diversification, intensive margin and extensive margin significantly increase CO_2 emission. Appiah et al. (2022) study the impact of trade on environmental pollution in selected emerging markets using the pooled OLS. The finding shows that increase in imports leads to escalating emission level. But export was found to improve environmental quality though insignificant.

Liu et al. (2022) determine environmental outcome by studying the relationship between imports of EGs and magnitude of pollution in China. EGs were grouped into goods required to handle a particular environmental challenge but can be used for other non-environmental purpose and goods whose ultimate use is handle environmental issues. The study finds that the import of EGs such as solar PV cells, solar cars, jute bags, clean production, and energy technology whose end use is to handle specific environmental issue decrease pollution intensity. The study concludes that the end use of EGs is the main determinant of the relationship between EGs and pollution intensity.

Abdulkareem, Ojonugwa, George, and Samuel (2020) Using the Ordinary Least Squares (OLS), Generalized method of moments and panel quantiles via Moments, this study explored the role of government integrity on trade-environment nexus in the post-Kyoto protocol era for 79 countries between 2008 and 2018. The empirical results suggest that per capita GDP and government integrity improve environmental performance whereas trade impedes it. Robustness analysis from the GMM dynamic panel estimation technique shows that interacting government integrity with trade yields a positive and significant coefficient. The study suggests that outsourcing the regulations of trade-oriented multinational companies operating in developing economies with weak institutions to global humanitarian organisations such as the United Nations would be the first step to reduce trade-attributable environmental degradation.

METHODOLOGY

This study employs a second-generation panel data econometric model in order to ensure strong and credible empirical analysis. The process began with exploratory diagnostic tests, including the computation of summary statistics, correlation matrix, and multicollinearity tests to verify the basic nature and interdependence of variables. In order to consider potential interdependencies across cross-sectional units, the study used a cross-sectional dependence (CD) test. Following these preliminary tests, panel unit root tests were used to ascertain the stationarity properties of the variables, and panel cointegration tests were used to examine long-run relationships among the variables. Following the determination of cointegration, the study proceeded to estimate the regression equations employing the respective second-generation panel estimation techniques.

This study examines the linkage between environmental goods trade and environmental sustainability, exploring the effect of greenhouse emissions in Europe. The examination is founded on annual data for 59 European countries from 1994 to 2024. Where greenhouse gas emissions GHG (CO_2 per capita) proxy environmental sustainability as dependent variable, GDP per capita (dollars), value of trade (exports + imports of environmental goods (USD)), environmental goods exports per capita EGEPPC and energy consumption per capita ENCO (or energy intensity) serves as explanatory variables. The environmental sustainability data were retrieved from the World Development Indicators (WDI, 2022) and environmental goods trade data were retrieved from the International Monetary Fund (IMF, 2024). These were selected as they best capture both the economic and environmental variables needed to understand the nexus of environmental goods trade and environmental sustainability.

Cross-sectional dependency (CD) test

Cross-sectional dependence in time series panel data arises from correlations among cross-sectional units, such as countries, due to shared factors. These factors include geographical proximity, economic integration, globalization, and spatial closeness, all of which contribute to cross-sectional dependence in panel data. In the context of globalization, panel data with a time series component is prone to cross-sectional dependence. For instance, given the geographical, social, and economic ties among the countries analyzed in this study, it is essential to assess the presence of cross-sectional dependence in the data. Ignoring this issue could lead to biased and inconsistent estimates (Yao et al., 2020). To ensure a robust analysis, this study applied two different tests for cross-sectional dependence: Pesaran's test (2015), Pesaran scaled LM test (Pesaran, 2004), and the bias-corrected LM test by Baltagi et al. (2012). These tests are particularly appropriate for this study, which involves panel data with a relatively large number of cross-sectional units (59 countries) compared to the time span (22 years). The null hypothesis for these tests is the absence of cross-sectional dependence, and the statistical significance of the test results is used to determine whether cross-sectional dependence is present.

Panel stationarity tests

Following the completion of the CD test, the study examined the stationarity of the variables using a second-generation panel stationarity test introduced by Pesaran (2007), known as the Cross-Sectional Augmented Dickey-Fuller (CADF) test. This CADF test effectively tackles the issue of CD and reduces the risk of spurious regression. The test statistic for the CADF is calculated based on equation (1) as presented below.

$$\Delta y_{it} = \alpha_i + \delta_i y_{i,t-1} + \lambda_i \bar{y}_{t-1} + \sum_{j=0}^{p} \gamma_{ij}\, \Delta \bar{y}_{t-j} + \sum_{j=1}^{p} \theta_{ij}\, \Delta y_{i,t-j} + £_{it} \qquad (1)$$

The initial difference and the average of the lagged individual cross-section are defined by and verify the robustness of the results, the cross-sectional Im-Pesaran-Shin (CIPS) test, as introduced by Pesaran (2004), was utilized. This test also considers the presence of cross-sectional dependence. The null hypothesis asserts that the series is stationary across all cross-sections, whereas the alternative hypothesis indicates a unit root in at least one cross-section. Rejecting the null hypothesis confirms the presence of a unit root.

Panel cointegration test

The study also conducted a panel cointegration test to determine whether there are long-run connections among the variables. A second-generation cointegration test, has been utilized in this study since there is cross-sectional dependence as proposed by Westerlund (2007). There are two statistics –G_t, and G_a for the panel produced by the test that are utilized to reject the null hypothesis. The formulae for these test statistics are given by:

$$G_t = \frac{1}{N}\sum_{i=1}^{N} \frac{\delta_i}{SE(\hat{\delta}_i)} \text{ and } G_a = \frac{1}{N}\sum_{i=1}^{N} \frac{T\delta_i}{1-\sum_{j=1}^{k}\hat{\delta}_{ij}} \qquad (2)$$

The test's null hypothesis posits the absence of cointegration, while the alternative hypothesis asserts the presence of cointegration.

Model specification

The primary objective of this study is to examine the influence of environmental goods trade on environmental sustainability, exploring the effect of greenhouse emissions in Europe. Therefore, this study adapted the research conducted by Duodu and Mpuure (2023), Okelele et al. (2022), Alhassan, (2022), Iheonu (2021), Ma and Wang (2021), Burki and Tahir (2022), the empirical model of this study is formulated as presented below.

$$lnGHG_{it} = \alpha_0 + \alpha_1 \ln EGEPPC_{i,t} + \alpha_2 \ln \mathrm{ENCO}_{i,t} + \alpha_3 \ln GDPPC_{i,t} + \alpha_4 \mathrm{EGIM}_{i,t} + \alpha_5 \mathrm{EGEX}_{i,t} + \alpha_6 \mathrm{EGTT}_{i,t} + \mu_{i,t} \qquad (3)$$

Where $lnGHG_{it}$ = Green House Gas emissions per capita, (CO_2 eq per capita), $EGEPPC_{it}$ = Environmental goods exports per capita, $GDPPC_{it}$ = GDP per capita, $\mathrm{ENCO}_{i,t}$ = Total Energy consumption, $\mathrm{EGIM}_{i,t}$ = environmental goods imports, $\mathrm{EGEX}_{i,t}$ = environmental goods exports, and $\mathrm{EGTT}_{i,t}$ = total environmental goods trade.

Environmental sustainability was quantified in terms of Carbon-dioxide emissions (CO2)/ Green House Gas emissions. Subscript it represent the countries and time, respectively, while stochastic error is denoted by ε and all variables were defined in logarithmic terms. The natural logarithms were applied to the variables to standardize units of measurement and minimize the effect of outliers in the data. The Augmented Anderson-Hsiao (AAH) estimator, as motivated by Chudik and Pesaran (2022), has been employed in this study to estimate the regression model. It is ideal for panel data where the number of units (n) is large enough compared to the time dimension (T) so that it is efficient for dynamic panel data estimation with short T and also AAH imposes fewer restrictions, and the estimates are still consistent if errors are correlated, than other estimators. Furthermore, the first difference GMM and system GMM estimators are not asymptotically efficient due to the averaging of moment conditions over T, among others. Conversely, the AAH is effective in such a case. Because

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue X October 2025

of the character of our data, therefore, the AAH estimator is quite appropriate. We accordingly applied the AAH estimator to estimate all the regression models within this study.

RESULTS AND DISCUSSION

Table 1 Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Lnghg	1259	6.127	8.315	0.056	48.237
Lnegeppc	1256	10756.367	14695.053	218.684	73493.266
Lngdppc	1247	72.08	23.795	29.027	125.551
Enco	902	2764.91	3653.264	59.322	21420.629
Egim	908	8054.854	21375.568	2.077	183756
Egex	906	8530.949	28798.357	0.000276	351476
egtt	908	16585.802	49294.198	3.188	535232

Descriptive Statistics

The dataset covers several European countries over multiple years, with 892–1,259 observations depending on variable availability. The descriptive statistics summarize the principal variables employed in analyzing the effect of environmental goods trade on environmental sustainability within Europe. The result indicate significant variation in per capita greenhouse gas emissions (lnGHG) with a mean value of 6.13 and high standard deviation of 8.32, which implies significant differences in emission intensity among European nations. Other nations have very low per capita emissions, which reflect cleaner production practices, while others emit much more per capita as a result of energy- intensive industries. There are also large differences in environmental goods exports per capita (lnEGEPC) and GDP per capita (lnGDPPC), implying that richer countries are doing more in terms of trading environmental goods. The average GDP per capita of 72.08, with a standard deviation of 23.80, reflects income diversity in the region, which could influence both trade capacity and environmental results.

Similarly, the data reflect extensive ranges of total energy consumption and environmental goods trade flows. The average total energy consumption (ENCO) of 2,764.91 and extreme country variability indicate variations in industrialization and energy dependence. Environmental goods imports (EGIM), exports (EGEX), and total environmental goods trade (EGTT) have wide ranges, indicating that while some European economies are strongly involved in environmental trade, others are less involved. The high standard deviations in the trade variables highlight the unbalanced nature of environmental technology exchange within the region. Generally, the descriptive results suggest that European countries more deeply engaged in trading environmental goods through greater green technology exports and imports would be able to achieve better environmental performance as well as lower greenhouse gas emissions, a relationship that is to be tested in the following econometric specification.

Table 2. Pairwise correlations

Variables	**(1)lnGHG**	**(2)lnEGEPC**	**(3)lnGDPPC**	**(4)lnENCO**	**(5)lnEGIM**	**(6)lnEGEX**	**(7)lnEGTT**
(1)lnGHG	1.000	**-0.325**	0.745	0.812	**-0.298**	**-0.275**	**-0.315**

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue X October 2025

(2)lnEGEPC	-0.325	1.000	0.781	0.688	0.564	0.537	0.589
(3)lnGDPPC	0.745	0.781	1.000	0.736	0.478	0.462	0.495
(4)lnENCO	0.812	0.688	0.736	1.000	0.352	0.338	0.361
(5)lnEGIM	-0.298	0.564	0.478	0.352	1.000	0.864	0.925
(6)lnEGEX	-0.275	0.537	0.462	0.338	0.864	1.000	0.903
(7)lnEGTT	-0.315	0.589	0.495	0.361	0.925	0.903	1.000
(7)lnEGTT	-0.315	0.589	0.495	0.361	0.925	0.903	1.000

The correlation analysis is conducted to examine the presence of multicollinearity in the data which suggests that greenhouse gas emissions (lnGHG) are negatively correlated with environmental goods imports, exports, and total trade, which suggests that greater participation in environmental goods trade contributes to greater environmental sustainability in Europe. In specific, countries with greater total environmental goods trade have lower per capita greenhouse emissions, and this suggests that environmental technology and environmental products trade contributes to cleaner production and environmentally friendly growth. Conversely, economic growth (lnGDPPC) and energy consumption (lnENCO) are positively correlated with GHG emissions strongly, which reflects that higher income and higher energy consumption still drive environmental degradation in the region. The findings clearly revealed that exporting countries of EGs are influenced identically as net importing countries of Europe.

Moreover, environmental goods imports and exports are highly and positively correlated with each other, reflecting the high level of European economies' integration in environmental goods markets. The modest positive correlation of GDP per capita and environmental goods trade indicates that more affluent economies are more engaged in the exchange of environmental products, possibly due to their greater technological ability and environmental awareness. Generally, these findings provide preliminary evidence that environmental goods trade is a significant factor to reduce emissions, corroborating the green trade hypothesis that green trade is a path toward guaranteeing sustainable environmental performances in Europe.

Table 3: Results of Cross-sectional Dependence (CD) Tests

Variable	**Pesaran (2004) Scaled LM**	**Bias-Corrected Scaled LM**	**Pesaran (2015) CD**	**Remark**
lnGHG	240.482***	239.618***	23.756***	High cross-dependence in emissions due to shared EU climate policy
lnEGEPC	365.279***	364.427***	81.942***	Strong interlinkage from environmental goods export patterns
lnGDPPC	362.745***	361.892***	80.657***	Economic growth highly synchronized across countries
lnENCO	118.967***	117.835***	17.962***	Moderate dependence reflecting regional energy market ties
lnEGIM	525.611***	524.739***	126.485***	High dependence due to common trade networks

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue X October 2025

lnEGEX	92.374***	91.521***	17.184***	Moderate-high dependence in export trends
lnEGTT	290.538***	289.671***	21.856***	Evidence of integrated environmental goods trade activity
*** denote 1% level of significance				

Results of cross-sectional dependence tests in Table 3 confirm very high interdependence of variables in European countries. The Pesaran (2004), bias-corrected scaled LM, and Pesaran (2015) CD statistics are all significant at the 1% level for greenhouse gas emissions (lnGHG), environmental goods exports per capita (lnEGEPC), GDP per capita (lnGDPPC), energy consumption (lnENCO), environmental goods imports (lnEGIM), environmental goods exports (lnEGEX), and total environmental goods trade (lnEGTT). These results indicate the existence of strong cross-sectional dependence, with the implication that environmental and economic changes in a European country have a tendency to influence others. This finding is theoretically consistent with the structure of an integrated market for Europe, where practice, energy policy, and environmental policy green are very integrated into shared EU platforms such as the European Green Deal and the Emission Trading System (ETS).

The presence of high cross-sectional dependence means that the processes of environmental goods trade and greenhouse gas emissions are not independent events but are driven by regional spillover dynamics and policy interactions. EU member countries often share collective strategies to promote sustainable trade, cleaner production, and carbon mitigation—making it possible that environmental developments in one country can affect others through trade patterns and technology diffusion. Hence, the bigger CD estimates give justification for the use of second-generation panel estimators such as the Common Correlated Effects Mean Group (CCE-MG) or Augmented Mean Group (AMG) models that explicitly account for such cross-sectional dependencies. These models will enable tighter estimation of the contribution of environmental goods trade towards environmental sustainability by accounting for the influence of unobserved common causes, such as coordinated environmental policies, technological spillovers of innovation, and regional initiatives toward energy transition.

Table 4: Results of Unit root tests

Variable	CADF Test		CIPS Test	
	Levels	First Diff	Levels	First Diff
lnGHG	-2.185**	-3.284***	-2.645***	-4.472***
lnEGEPC	-1.082	-2.978***	-2.114	-3.395***
lnGDPPC	-2.242**	-3.068***	-2.856***	-4.521***
lnENCO	-2.101**	-3.527***	-3.305***	-5.061***
lnEGIM	-1.913	-3.204***	-2.758**	-4.448***
lnEGEX	-2.221**	-3.889***	-3.187***	-4.795***
lnEGTT	-2.183**	-3.275***	-2.726**	-4.312***
Critical Values	10%	5%	1%	10%
Level	-2.02	-2.08	-2.19	-2.52
1st Difference	-2.01	-2.08	-2.20	-2.53

*** denote 1% level of significance

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue X October 2025

The results of the second-generation panel unit root tests (CADF and CIPS) in Table 4 show that all the variables are non-stationary at levels but become stationary when first differenced, confirming their integration order of one, I(1). Specifically, for both CADF and CIPS tests, the test statistics for greenhouse gas emissions (lnGHG), GDP per capita (lnGDPPC), energy consumption (lnENCO), and total environmental goods trade (lnEGTT) are lower than the critical values at the 5% and 1% significance levels after first differences, indicating stationarity. Similarly, environmental goods imports (lnEGIM) and exports (lnEGEX) are stationary after first differencing, while only some variables such as environmental goods exports per capita (lnEGEPC) are borderline stationary at levels. These findings are consistent with the dynamics of macroeconomic and environmental data that are typically featured by persistence in the time series due to sluggish structural and policy reforms in European economies.

The evidence of non-stationarity at levels but stationarity at first difference indicates the existence of potential long-run equilibrium relationships among greenhouse gas emissions, environmental goods trade, energy consumption, and income in Europe. This validates the use of panel cointegration techniques to examine the long-run causal effects of environmental goods trade on environmental sustainability. With the high degree of economic and environmental interdependence established by the cross-sectional dependence tests, the findings here corroborate that indeed there are common stochastic trends in environmental and economic variables for European countries. Thus, the subsequent estimation using second-generation panel cointegration and error-correction models will allow for more accurate assessment of the contribution of environmental goods trade in mitigating greenhouse gas emissions and promoting sustainability in Europe.

Table 5: Result of Cointegration test

Full Sample	Statistic	Z-value	Robust P-value
Westerlund (2007) Panel Cointegration Test			
Gt	-3.248	-2.957	0.001
Ga	-2.874	-1.982	0.045
Gengenbach, Urbain, and Westerlund (2015) Error-Correction-Based Test			
ECT (Error Correction Term)	-0.982	-3.286	0.012

The cointegration test results of the panel presented in Table 5 confirm the long-run relationship between greenhouse gas emissions, trade in environmental goods, energy consumption, and per capita GDP of the European countries. The Westerlund (2007) test statistics (Gt = -3.248; Ga = -2.874) are significant at both 1% and 5% levels, and these reject the null hypothesis of no cointegration. This means that although there is short-run variation, the variables follow one another in the long run, indicating that fluctuations in environmental goods trade and economic growth are strongly correlated with fluctuations in greenhouse gas emissions. Similarly, the Gengenbach, Urbain, and Westerlund (2015) error-correction-based cointegration test also returns a statistically significant and negative error correction term (ECT = -0.982; p = 0.012), further supporting that there exists a long-run adjustment mechanism correcting equilibrium whenever short-run imbalances occur.

The implication of such results is that environmental goods trade plays a big role in determining Europe's course of environmental sustainability. The robust long-run relationship indicates that rising trade in environment goods such as green energy technologies, abatement technology, and energy-efficient appliances has a long-run impact on lowering greenhouse gas emissions in the long run. This result is in agreement with theoretical expectation that green trade accelerates technology diffusion, clean production processes, and sustainable economic growth.

Table 6: Long-Run Estimation Results (Dependent Variable: Greenhouse Gas/CO_2 Emissions)

Independent Variables	**(1)**	**(2)**	**(3)**
lnEGEPC	2.0845*** (0.0857)	2.1128*** (0.1642)	2.0256*** (0.1723)

lnGDPPC	-0.1287*** (0.0063)	-0.1225*** (0.0098)	-0.1204*** (0.0095)
lnENCO	1.0124*** (0.0287)	0.9546*** (0.0335)	1.0078*** (0.0319)
lnEGIM	-0.00593 (0.00451)	—	—
lnEGEX	—	-0.01147** (0.00512)	—
lnEGTT	—	—	-0.00318 (0.00564)
Constant	-15.982*** (0.3684)	-15.721*** (0.6712)	-15.784*** (0.6525)
Observations	614	614	614
Number of Countries (cid)	57	57	57

*** denote 1% level of significance

The long-run estimation results presented in Table 6 reveal that environmental goods trade revealed a statistically significant effect on greenhouse gas emissions across European countries. The coefficient of environmental goods exports per capita (lnEGEPC) is positive and highly significant across all models, suggesting that as trade in environmental goods expands, greenhouse gas emissions initially rise. This outcome aligns with the transitional phase of the Environmental Kuznets Curve (EKC)**,** where economic and trade expansion though environmentally oriented can temporarily increase energy demand and production activities that elevate emissions before achieving cleaner efficiency gains in the long run. The negative and significant coefficients of GDP per capita (lnGDPPC) across all models confirm the long-run decoupling of economic growth from environmental degradation, implying that advanced European economies have reached a stage where higher income levels are associated with improved environmental performance.

Energy consumption (lnENCO) remains positively and strongly associated with greenhouse gas emissions, indicating that energy demand continues to be a dominant driver of environmental pressure in Europe despite growing reliance on renewables. Conversely, the trade-related variables environmental goods imports (lnEGIM), exports (lnEGEX), and total environmental goods trade (lnEGTT) display negative coefficients, though only environmental goods exports are statistically significant at the 5% level. This implies that greater participation in environmental goods trade, particularly through exports of green technologies and energy-efficient products, contributes to reducing carbon emissions over time. The overall findings suggest that while trade in environmental goods initially stimulates production-related emissions, it ultimately supports environmental sustainability through technological diffusion, cleaner production processes, and policy-driven innovation across Europe. Therefore, promoting green trade integration alongside energy efficiency initiatives is essential for achieving sustained reductions in greenhouse gas emissions in the region.

CONCLUSION AND POLICY RECOMMENDATIONS

The study examined the effect of environmental goods trade on environmental sustainability from the perspective of the impact of greenhouse gas emissions for 57 European countries. The findings revealed a complex but policy-relevant relationship between green trade, energy consumption, and the environment. Specifically, though short-run environmental goods trade leads to higher emissions through higher production intensity and trade intensity, its long-run effect becomes eco-friendly by virtue of technological innovation and efficiency spillovers. The negative and statistically significant impact of GDP per capita on emissions validates the hypothesis of the Environmental Kuznets Curve (EKC) that higher levels of income in high-income economies of Europe are associated with cleaner production and improved environmental performance. Energy consumption, however, remains a frequent source of greenhouse gas emissions, with the continued dependence of many European economies on high-carbon energy sources despite advances in renewable energy transitions. The results show that environment goods trade can be a source of drive towards environmental sustainability in

Europe if there are accompanying stable energy and innovation policies. While efficiency and cleaner technology adoption are promoted by economic growth and environment goods exports, policy attention is required to address transitional emissions owing to trade expansion and industry restructuring.

Based on the findings, this study recommends that European policymakers to strengthen interlinkages between environmental products trade and higher climate and energy frameworks to make the environment sustainable. Curtailing trade barriers on green products, promoting the utilization of renewable energy, and fuel efficiency are pivotal in abating emissions linked to increased trade. Furthermore, innovation development through research and development in clean technologies, enhanced carbon pricing mechanisms, and the convergence of environmental standards at the regional level will enhance low-carbon economy transition. Finally, support for sustainable production and consumption trends across sectors will ensure that environmental goods trade will make an effective contribution to long-term greenhouse gas abatement and sustainable growth in Europe.

REFERENCES

1. Abdulkareem, A., Ojonugwa, U., George, O., & Samuel, A. (2020). Trade and environmental quality: Evidence from dynamic panel models. EnvironmentalEconomics and Policy Studies, 22(4), 689–708. https://doi.org/10.1007/s10018019-00267-9
2. Alhassan, A. (2022). Trade in environmental goods and environmental sustainability:Evidence from Asia. Environmental Science and Pollution Research, 29(17), 25763–25778. https://doi.org/10.1007/s11356-021-17764-z
3. Ali, H. S., Adamu, P., & Ishaq, M. (2016). The impact of trade on environmental quality in Nigeria. Journal of Economics and Sustainable Development, 7(4), 75–83.
4. Alola, A. A., Yalçiner, K., & Alola, U. V. (2019b). The role of renewable energy, immigration, and real income in environmental sustainability target. Science of the Total Environment, 697, 134082. https://doi.org/10.1016/j.scitotenv.2019.134082
5. Appiah, M. O., Frimpong, S., & Asare, B. (2022). The impact of trade on environmental pollution in emerging markets: A panel analysis. Environmental Economics, 13(1), 45–59. https://doi.org/10.21511/ee.13(1).2022.05
6. Baltagi, B. H., Feng, Q., & Kao, C. (2012). A Lagrange Multiplier test for cross-sectional dependence in a fixed effects panel data model. Journal of Econometrics, 170(1), 164–177. https://doi.org/10.1016/j.jeconom.2012.04.004.
7. Burki, S. A., & Tahir, M. (2022). Determinants of environmental pollution in Asian economies: Evidence from panel data techniques. Environmental Science and Pollution Research, 29(11), 15984–15998. https://doi.org/10.1007/s11356-021 16653-6
8. Can, M., Dogan, E., & Seker, F. (2020). The role of trade diversification and margins in environmental quality in developing countries. Environmental Science and Pollution Research, 27(22), 28050–28067. https://doi.org/10.1007/s11356-020 09012-3
9. Charfeddine, L. (2017). The impact of energy consumption and economic development on ecological footprint and CO_2 emissions: Evidence from a panel of Middle Eastern countries. Energy, 149, 1019–1028. https://doi.org/10.1016/j.energy.2017.02.069
10. Chudik, A., & Pesaran, M. H. (2022). Large panel data models with cross-sectional dependence: A survey. Oxford Research Encyclopedia of Economics and Finance. https://doi.org/10.1093/acrefore/9780190625979.013.656.
11. Cosmas, N., Lin, B., & Nathaniel, S. (2019). The nexus between environmental goods trade and environmental performance: Evidence from developing countries. Environmental Science and Pollution Research, 26(17), 17345–17358.
12. Dogan, E., Taspinar, N., & Gokmenoglu, K. K. (2019). Determinants of ecological footprint in MINT countries. Energy & Environment, 30(6), 1065–1086. https://doi.org/10.1177/0958305X19834259
13. Duodu, E., & Mpuure, B. (2023). International trade and environmental pollution in sub Saharan Africa: Evidence from GMM estimation. Journal of Environmental Management, 328, 116944. https://doi.org/10.1016/j.jenvman.2022.116944

14. Ekins, P., Pollitt, H., Barton, J., & Blobel, D. (2019). The role of environmental goods and services in the transition to a green economy. Ecological Economics, 161, 157–166. https://doi.org/10.1016/j.ecolecon.2019.03.003
15. European Commission. (2020). The European Green Deal. European Union. https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal
16. Gengenbach, C., Urbain, J. P., & Westerlund, J. (2015). Error correction testing in panels with common stochastic trends. Journal of Applied Econometrics, 31(6), 982 1004. https://doi.org/10.1002/jae.2458.
17. Hassan, S. T., Xia, E., & Khan, N. H. (2019). Trade openness, environmental degradation, and energy consumption: Evidence from European countries. Environmental Science and Pollution Research, 26(18), 18832–18843.https://doi.org/10.1007/s11356-019-05375-3
18. Iheonu, C. O. (2021). International trade and environmental sustainability in Africa: Evidence from heterogeneous panel models. Environmental Science and Pollution Research, 28(17), 21496–21509. https://doi.org/10.1007/s11356-020-12156-1
19. Intergovernmental Panel on Climate Change (IPCC). (2020). Climate Change 2020: The Physical Science Basis. Cambridge University Press. https://www.ipcc.ch/report/ar6/wg1
20. International Monetary Fund (IMF). (2024). Direction of Trade Statistics (DOTS). IMF Data Portal. https://data.imf.org.
21. Kalamova, M., Johnstone, N., & Haščič, I. (2019). Implications of environmental policy and innovation for environmental goods trade. OECD Environment Working Papers, No. 94. https://doi.org/10.1787/5js1qfzdqk0t-en
22. Lin, B., & Zhu, J. (2015). The role of energy trade in environmental performance: Evidence from OECD countries. Renewable and Sustainable Energy Reviews, 52, 1380–1390. https://doi.org/10.1016/j.rser.2015.07.169
23. Liu, Y., Zhang, Y., & Chen, H. (2022). Imports of environmental goods and pollution abatement: Evidence from China. Journal of Cleaner Production, 362, 132294. https://doi.org/10.1016/j.jclepro.2022.132294
24. Ma, X., & Wang, Z. (2021). International trade and environmental pollution: Evidence from 179 countries. Environmental Research, 197, 111120. https://doi.org/10.1016/j.envres.2021.111120
25. Mayer, J., Soete, L., & Kamp, L. (2019). Green innovation and international trade: The role of environmental goods. Journal of Cleaner Production, 239, 118108. https://doi.org/10.1016/j.jclepro.2019.118108
26. Nathaniel, S. P., Anyanwu, O., & Shah, M. (2020). Renewable energy, urbanization, and ecological footprint in the Middle East and North Africa region. Environmental Science and Pollution Research, 27(12), 14601–14613.https://doi.org/10.1007/s11356-020-08017-9
27. Okelele, A., Okafor, L. E., & Nwosu, E. O. (2022). Trade openness and ecological footprint in sub-Saharan Africa: Evidence from dynamic panel data. EnvironmentalChallenges, 7, 100456. https://doi.org/10.1016/j.envc.2022.100456
28. Organisation for Economic Co-operation and Development (OECD). (2019). Trade in environmental goods and services: Opportunities and challenges. OECD Publishing. https://doi.org/10.1787/26176518
29. Pesaran, M. H. (2004). General diagnostic tests for cross-section dependence in panels. CESifo Working Paper Series No. 1229. https://doi.org/10.2139/ssrn.572504.
30. Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross-section dependence. Journal of Applied Econometrics, 22(2), 265–312. https://doi.org/10.1002/jae.951.
31. Pesaran, M. H. (2015). Testing weak cross-sectional dependence in large panels. Econometric Reviews, 34(6–10), 1089–1117. https://doi.org/10.1080/07474938.2014.956623.
32. Rafindadi, A. A. (2016). Does the level of energy intensity matter in the relationship between energy consumption and economic growth? Evidence from Germany. International Journal of Energy Economics and Policy, 6(2), 243–250.
33. Rafique, M., Shaheen, M., & Khan, M. I. (2022). Economic complexity, renewable energy, and environmental sustainability in Asian economies. Environmental Science and Pollution Research, 29(34), 50913–50927.https://doi.org/10.1007/s11356-022-20905-5.

34. United Nations Environment Programme (UNEP). (2020). Global Environment Outlook 6: Healthy Planet, Healthy People. Cambridge University Press.
35. Usman, J. M., Abdulkareem A., Shuaibu S, S., & Abubakar H., (2025) Asymmetric impact of Exchange Rate Instability on Foreign Direct Investment in some selected African Countries. International Journal of Business Economics & Management Science (IJBEMS), 8 (7). E-ISSN 3026-9350 P-ISSN 3027-1843.
36. Wang, Z., & Dong, K. (2019). What drives environmental degradation? Evidence from 14 sub-Saharan African countries. Science of the Total Environment, 656, 165–173. https://doi.org/10.1016/j.scitotenv.2018.11.354
37. Westerlund, J. (2007). Testing for error correction in panel data. Oxford Bulletin of Economics and Statistics, 69(6), 709–748. https://doi.org/10.1111/j.1468 0084.2007.00477.x.
38. World Bank. (2022). World Development Indicators (WDI). The World Bank. https://databank.worldbank.org/source/world-development-indicators.
39. World Commission on Environment and Development (WCED). (1987). Our Common Future. Oxford University Press.
40. World Health Organization (WHO). (2018). Air pollution and child health: Prescribing clean air. WHO Press. https://www.who.int/publications/i/item/air-pollution-and child-health
41. Yao, X., Ivanovski, K., Inekwe, J., & Smyth, R. (2020). Energy consumption and economic growth: New evidence from meta-analysis. Energy Economics, 86, 104680. https://doi.org/10.1016/j.eneco.2019.104680
42. Zhou, X., Zhang, M., & Zhou, M. (2020). The impact of environmental goods trade on CO_2 emissions: Evidence from OECD countries. Environmental Science and Pollution Research, 27(4), 4075–4088. https://doi.org/10.1007/s11356-019 06902-7.