Research in Globalization 9 (2024) 100240

Contents lists available at ScienceDirect

Research in Globalization

journal homepage: www.sciencedirect.com/journal/research-in-globalization

The environmental impact of international trade in Sub-Saharan Africa: Exploring the role of policy and institutions for environmental sustainability

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A R T I C L E I N F O

Keywords:
Environmental degradation
Trade openness
Exports
Imports
PIES
SSA

A B S T R A C T

Considering the potential role of environmental institutions in abating environmental pollution, this study deviates from previous studies by assessing how policy and institutions for environmental sustainability (PIES) mitigate the adverse effects of aggregate and disaggregated trade on the environment in Sub-Saharan Africa (SSA). Using Driscoll and Kraay method, generalized method of moments, and Dumitrescu and Hurlin causality test on data from 2005 to 2020 for 24 SSA countries, the results show that the adverse effects of overall and disaggregated trade on environmental degradation significantly reduces in the presence of PIES. The causal analysis revealed a bidirectional relationship between total trade, exports, imports, and environmental degradation. The study concludes that international trade cannot guarantee environmental sustainability in light of the 2030 SDGs without effective PIES. Therefore, the study calls for the strengthening of PIES to ensure environmental sustainability even as SSA countries move to deepen intra and inter-continental trade within the context of the African Continental Free Trade Area Agreement (AFCFTA).

1. Introduction

The growing interconnection and integration of economies have made international trade a crucial component of growth and development (Yasmeen et al., 2018; Wenlong et al., 2022). As a result, trade facilitates the dissemination of technology across borders, encourages competition in the global market, and redistributes resources (Ibrahim & Law, 2016; Duodu & Baidoo, 2020; Ibrahim & Ajide, 2022a; Jiahao et al., 2022; Duodu et al., 2024). In this context, Choksi et al. (1991) identified three effects-the scale effect,[4] technical effect,[5] and composition effect[6] (commonly known as the trio effect)-that enhance international trade, boost economic progress, stimulate domestic production, and promote the adoption of sustainable technologies for environmental conservation. Despite the potential advantages of trade as a catalyst for growth and development, a longstanding debate continues among policymakers and academics about whether trade is beneficial or detrimental to the environment, especially in developing countries. This debate partly stems from concerns that environmental pollution industries may relocate to countries with more lenient environmental regulations as a result of trade liberalization[7] (Salahuddin

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4 Scale effect of trade positively affect environmental degradation due to the increasing volume of production.
5 Technical effect negatively affects environmental degradation because of grimy production processes.
6 Composition effect can be negative or positive depending on the comparative advantage and the strength of the environmental policy of a country.
7 In terms of environmental pollutants.

https://doi.org/10.1016/j.resglo.2024.100240
Received 8 January 2024; Received in revised form 10 June 2024; Accepted 27 July 2024
Available online 7 August 2024

et al., 2018). In addition, Dong et al. (2018) and Weber & Sciubba (2019) argue that environmental pollution and excessive resource usage are mainly attributed to population growth and urbanization. This is because these factors intensify trade-related activities and their associated energy consumption needs. Consequently, environmental degradation caused by increased economic activities, including trade, has become a matter of concern, especially in Sub-Saharan Africa (SSA).

In SSA, the ongoing reliance on fossil energy consumption through imports continues to harm the environment by increasing CO_2 emissions (Khan et al., 2021; Ibrahim & Ajide, 2022a). This results in a compromised quality of the environment, affecting both health and the ecosystem (Duodu et al., 2022). According to the Environmental Kuznets Curve, increased industrial activities have detrimental effects on the environment, particularly in developing countries (Grossman & Krueger, 1991). The OECD (2012) proposed taking deliberate steps, including climate financing, to address environmental degradation in developing countries. Additionally, Brundtland et al. (1987) emphasized the need for governments to create a more sustainable future by adjusting their growth policies, such as trade policies, to consider environmental sustainability. This is crucial because it aligns with the 2030 Sustainable Development Goals 13 and 15 (SDGs), which aim to combat global greenhouse gas emissions, including CO_2 emissions, by 2050 (UNDP, 2015[8]). It appears that achieving environmental sustainability, particularly in the context of the SDGs 13 and 15, may be a difficult task without effective and well-functioning environmental institutions. This is because these institutions have the ability to ensure that green policies, including international trade policies, are implemented and enforced in order to achieve the SDGs.

Studies conducted both within and outside of the SSA region have demonstrated that the quality of institutions plays a crucial role in fostering environmental sustainability (Abid, 2016; Yasmeen et al., 2018; Acheampong & Dzator, 2020; Duodu et al., 2021). However, numerous research studies focused on SSA have not yet acknowledged the potential influence of environmental institutions in the connection between trade and the environment (Asongu & Odhiambo, 2021; Iheonu et al., 2021; Nwani et al., 2022; Okelele et al., 2022; Yılmaz, 2023; Baajike et al., 2024). While Ibrahim & Law (2016), Ibrahim & Ajide (2022a), and Maji et al. (2023) attempted to utilize political institutions, such as political stability, good governance, rule of law, and government effectiveness, as indicators of institutions when examining the relationship between trade and CO_2 emissions in SSA, this study argues that these indicators, due to their broad scope, have limited impact on the environment. Although these institutions may help to mitigate environmental degradation by enforcing environmental regulations, they do not directly measure the preservation of natural resources and pollution management. Moreover, the studies in SSA did not explore the function of environmental institutions in mitigating the particular consequences of imports and exports on environmental sustainability. This aspect is essential in guiding policymakers in determining forms of trade that could potentially cause less damage to the environment. As political institutions lack a direct association with the environment, this study adopts the approach of the World Bank and employs the policy and institutions for environmental sustainability (PIES) as an indicator of environmental institutions. The PIES assesses the extent to which environmental policies promote sustainable use and conservation of natural resources, as well as the management of pollution (WDI, 2022). This measure is more oriented towards environmental protection. This is because countries with effective policies and institutions for safeguarding and promoting sustainable use of natural resources and efficient management of pollution are more likely to implement stringent environmental policies to achieve environmental sustainability.

The study distinguishes itself from prior research, especially in the domain of SSA, by employing PIES and their relationship with trade, both in their aggregated and disaggregated forms, to thoroughly investigate the environmental impact of international trade. Consequently, this study contributes to the studies on the trade-carbon dioxide emissions nexus in SSA by (i) Utilizing PIES instead of traditional "political" measures of institutions to investigate the role of institutions in fostering a sustainable environment in SSA. (ii) Assessing the complementary effect of PIES and total trade, exports, and imports on environmental degradation. By examining the disaggregated impact of trade, this research aims to identify which form of trade significantly contributes to or mitigates environmental quality. The results indicate that trade openness, exports, and imports contribute to a decrease in environmental degradation when accompanied by PIES. Therefore, this study makes a substantial contribution to the existing studies on the importance of well-functioning environmental institutions. This contribution is particularly relevant as SSA countries continue to embrace intra- and intercontinental trade opportunities.

The remainder of the study is structured as follows; Section 2 reviews relevant studies on the subject. Section 3 describes the data and empirical methodology. Section 4 presents the results and discussions. Finally, concluding remarks and policy implications are presented in section 5.

2. Literature review

The two main theories that address the relationship between globalization (including trade liberalization) and environmental degradation are the pollution haven hypothesis (hereafter the haven hypothesis) and the pollution halo hypothesis (hereinafter the halo hypothesis). The haven hypothesis posits that as a result of trade liberalization and relaxed environmental regulations, polluting companies from developed countries move to developing countries to increase pollution levels, and consequently, environmental degradation in these countries (Walter & Ugelow, 1979). This view suggests that globalization, including trade openness without strong environmental institutions, can harm the environment, especially in developing countries. In contrast, the halo hypothesis argues that globalization can promote a cleaner environment by stimulating the transfer of greener technologies and effective environmental management practices. This occurs because clean and efficient energy is utilized through greener technologies, which in turn leads to lower carbon emissions (Eskeland & Harrison, 2003). Thus, the halo hypothesis posits that globalization or liberalization improves environmental quality through the diffusion of greener technologies. These differing views on the relationship between liberalization and environmental degradation have led to numerous empirical studies in the trade-environment nexus in both SSA and other regions. The following subsections will review relevant empirical studies on trade, institutions, and environmental degradation.

2.1. International trade and environmental degradation

Several studies have been conducted in the past to investigate the impact of trade liberalization on the environment. For example, Baajike et al. (2024) analyzed the relationship between trade intensity and efficiency and CO_2 emissions using a comprehensive dataset of SSA countries. Their findings revealed that trade intensity increases emissions, while trade efficiency reduces CO_2 emissions. In another study, Yılmaz (2023) used the vector error correction model to examine how trade openness affects CO_2 emissions in SSA. The results showed a positive bidirectional causality between trade and CO_2 emissions. Additionally, Nwani et al. (2022) employed the method of moments quantile regression approach to assess the role of renewable energy in the effects of remittances and trade liberalization on the environment in SSA net-importing economies. The study found that trade liberalization significantly increases CO_2 emissions through imports but not through exports. However, Okelele et al. (2022) conducted a study on the impact of trade openness and FDI on the ecological footprint in 23 SSA countries

[8] United Nations Development Programme.

and found that trade openness significantly reduces the ecological footprint.

Moreover, Iheonu et al. (2021) employ panel quantile regression on data from 1990 to 2016 for 34 SSA countries to examine if environmental sustainability is influenced by trade, urbanization, renewable energy, and economic growth. The study reveals that trade improves environmental quality and that there exists a bidirectional causality between trade and CO_2 emissions. Tenaw & Beyene (2021) also explored environmental sustainability and economic development in SSA spanning 1990–2015 and used the panel autoregressive distributed lag (ARDL). Their results show that trade openness in the long run has a detrimental effect on the environment. Similarly, Asongu & Odhiambo (2021) used the generalized method of moments (GMM) to explore the trade and FDI thresholds of CO_2 emissions for a green economy in SSA and found that trade openness positively promotes CO_2 emissions. This result is supported by Acheampong et al. (2019), who examined the effect of globalization and renewable energy on CO_2 emissions in SSA and found that trade increases CO_2 emissions. Using both fully modified and dynamic ordinary least squares (FMOLS and DOLS), Kwakwa & Adu (2015) estimated the effects of income, energy consumption, and trade openness on carbon emissions spanning 1977–2012. They found that trade openness inelastically increases CO_2 emissions. From the perspective of SSA, it is obvious that a trade-environment nexus has been established with mixed results. However, not much can be said about whether the specific effects of imports and exports matter in environmental degradation and the mitigating role of institutions, specifically PIES, with international trade (both aggregate and disaggregated) on environmental degradation. Therefore, this study complements the existing research on SSA by addressing these gaps.

Moving to studies outside SSA, Kou et al. (2023) utilized a multi-regional input–output model to analyze CO_2 emissions and value-added trade patterns across approximately 189 countries. Their analysis revealed that per-unit value-added CO_2 emissions via trade decreased in most countries. In related a study, Khan et al. (2021) employed fixed-effect and GMM to estimate the relationship between renewable energy consumption, trade openness, and environmental degradation in both developing and developed countries. The study revealed that trade openness tends to improve environmental quality by reducing CO_2 emissions in developed countries, while it degrades environmental quality in developing countries. Asiedu et al. (2021), in their work on Belgium, the United States, and Canada, used the panel ARDL model and observed that trade openness promotes CO_2 emissions. Furthermore, Ibrahim & Ajide (2022a) employed the GMM method to investigate whether the environmental quality of some selected African countries is influenced by trade facilitation. They revealed that African countries can reduce pollution through trade facilitation. Muhammad et al. (2020) employed panel quantile regression and two-stage least squares on data from 65 Belt and Road Initiative countries to investigate the link between trade, urbanization, and CO_2 emissions. Their study revealed that in low- and high-income countries, exports decreased carbon emissions, while in lower-middle-income countries, CO_2 emissions increased. Their study further shows that imports increase carbon emissions in low-income countries while significantly decreasing CO_2 emissions in middle- and high-income countries. Also, Boamah et al. (2017) used quantile regression and DOLS and found that import growth in China harms CO_2 emissions at the 10th quantile but has a positive effect at the 20th-90th quantiles. Additionally, Dogan et al. (2017) and Dogan & Turkekul (2016) examined the trade-environment nexus using the FMOLS and ARDL approaches, respectively. They both show that international trade leads to environmental improvements. Again, Ren et al. (2014) used data from China's industrial sectors and examined the relationship between international trade, FDI, and CO_2 emissions using the GMM method. The study indicated that CO_2 emissions increased rapidly due to China's growing trade surplus, which worsens the environmental quality of China. The findings further show that both imports and exports are insignificant to CO_2 emissions in China. Again, mitigating role of institutions, specifically PIES, in the relationship between international trade (both aggregate and disaggregated) and environmental degradation has not been considered, indicating a need for further research.

2.2. International trade, institutions, and environmental degradation

The proposition in the haven hypothesis suggests that weak or lax environmental institutions induce pollution. Several studies have examined the role of institutions in the trade-environment nexus. Although most studies used political institutions, such as the rule of law, government effectiveness, and control of corruption as proxies for environmental institutions, they revealed that strong institutions enhance environmental quality. For example, Maji et al. (2023) used the system-GMM method and data from SSA to understand how institutional quality influences green trade to reduce CO_2 emissions. Their study shows that trade itself increases emissions in SSA. However, improving institutional quality towards green trade lowers CO_2 emissions. Similarly, Ibrahim & Ajide (2022b) examined trade facilitation, institutions, and environmental sustainability in SSA. Using the GMM, they found that institutions and their interactions with trade facilitation promote environmental sustainability.

Moreover, Wenlong et al. (2022) examined energy, institutional quality, trade, and CO_2 emissions in 10 Asian countries using both the augmented mean group and the common correlated effect mean group methods. Their study concludes that trade and institutional quality increase CO_2 emissions. Similarly, Acheampong & Dzator (2020) used data from 2000 to 2015 for 45 countries to examine whether environmental quality in SSA is influenced by the quality of institutions. With the GMM estimator, they found that trade openness increases CO_2 emissions, while institutions improve the quality of the environment by reducing CO_2 emissions. Furthermore, Yasmeen et al. (2018) employed GMM to examine the trade-environment nexus in 117 countries from five regions, including SSA. They found that the complementary effect of institutions and trade resolves environmental problems. Abid (2016) employed GMM on data spanning 1996–2010 to examine the impact of financial, economic, and institutional factors on environmental sustainability in 25 SSA countries. The study noted that institutions improved environmental sustainability. In another study, Ibrahim & Law (2016) investigated the effects of institutions on environmental degradation using data from 40 SSA countries. They found that trade openness has a detrimental effect on countries with low institutional quality and is beneficial for countries with high institutional quality. Intriguingly, these studies focus solely on political institutions and fail to address the complementary role of institutions in the specific effects of exports and imports on the environment.

2.3. Literature gaps

The studies reviewed thus far has produced mixed results, with some studies supporting the haven hypothesis (Acheampong et al., 2019; Asongu & Odhiambo, 2021; Tenaw & Beyene, 2021; Nwani et al., 2022; Wenlong et al., 2022; Baajike et al., 2024) and others supporting the halo hypothesis (Dogan & Turkekul, 2016; Iheonu et al., 2021; Khan et al., 2021; Okelele et al., 2022; Kou et al., 2023). However, these empirical studies have revealed a knowledge gap in assessing the role of environmental institutions in the specific effects of exports and imports on trade-CO_2 emissions in SSA. While Nwani et al. (2022) examine the differential impact of exports and imports on CO_2 emissions, they do not evaluate the complementary role of environmental institutions in the relationship between exports and imports, and environmental degradation. Furthermore, studies such as Ibrahim & Law (2016), Ibrahim & Ajide (2022b), and Maji et al. (2023), which account for institutions in the trade-environment relationship in SSA, do not consider the potential specific effects of exports and imports. Moreover, they rely on political measures of institutions (political stability, good governance, rule of law, government effectiveness, etc.), which have no direct implications for environmental protection. In light of these limitations, the present study employs PIES to assess the extent to which environmental institutions mitigate the effect of international trade on environmental degradation in SSA.

3. Empirical methodology

This section presents the empirical model specification, data and variable description, and the estimation strategy for the study.

3.1. Empirical model specification

The study used the stochastic impact regression on population, affluence, and technology (STIRPAT) model by Dietz & Rosa (1994) to investigate the connection between international trade and environmental degradation. Following Duodu et al. (2022), the study modified the STIRPAT model to capture the role of PIES. Furthermore, urbanization and economic growth are used as proxies for population and affluence, respectively. It is worth mentioning that international trade (IT) affects technology (T) in the model through diffusion, i.e., $T = f(IT)$. This helps to assess the effect of international trade on environmental degradation. The modified STIRPAT is therefore expressed in equation (1).

$$I_{it} = \alpha IT_{it}^{\delta_1} PIES_{it}^{\delta_2} EG_{it}^{\delta_3} URB_{it}^{\delta_4} \boldsymbol{X}_{it}^{\delta_5} \epsilon_{it} \tag{1}$$

Where I, IT, PIES, EG, URB, and **X** represent pollution emissions [hereafter environmental degradation (ED)], international trade (measured by trade openness, exports, and imports), policy and institutions for environment sustainability (PIES), urbanization, economic growth, and a vector of control variables [foreign direct investment (FDI), renewable energy (RE), and industrialization (IND)], respectively. The ε denotes the stochastic error term and $\delta_1 \cdots\cdots\cdots \delta_5$ are the respective elasticities to be estimated. Equation (1) is then expressed in functional form as in equation (2).

$$ED = f(IT, PIES, EG, URB, \boldsymbol{X}) \tag{2}$$

To ascertain the complementary role of PIES, the study augmented equation (2) with the interaction between PIES and international trade measures. This presents equation (3) for estimation.

$$\begin{aligned} lnED_{it} = {} & \alpha + \delta_1 IT_{it} + \delta_2 PIES_{it} + \delta_3 (PIES^*IT)_{it} + \delta_4 lnEG_{it} + \delta_5 lnURB_{it} \\ & + \boldsymbol{\delta_6 lnX_{it}} + \gamma_t + \varphi_i + \epsilon_{it} \end{aligned} \tag{3}$$

Where all variables are as defined in equation (1). The $(PIES^*IT)$ captures the complementary effect of international trade and PIES on environmental degradation. The γ_t and φ_i denote the fixed-effect and the country-specific effects, respectively.

3.2. Estimation strategy

The study begins the estimations by first testing for cross-sectional dependence (CD) using both the Pesaran (2004) and Pesaran (2015) CD tests. The test for CD remains crucial in a panel study as it informs the choice of a suitable estimation technique. Indeed, Pesaran (2007) postulates that the presence of CD could lead to inconsistent and biased results. Pesaran (2004) and Pesaran (2015) CD tests have the null hypothesis of cross-sectional independence and weak cross-sectional dependency, respectively. Thus, this study employed Harris & Tzavalis (1999), and Im et al. (2003) unit root tests for stationarity. In these tests, failure to reject the null hypothesis indicates that the series has a unit root. It's important to ascertain the stationarity properties of the variables because estimating non-stationary variables with an inappropriate model could lead to spurious estimates. Afterward, the study used the Driscoll & Kraay (1998) estimation method as a baseline for the model. The D-K estimation is used as a baseline in this study, since its standard errors are robust to CD, heteroskedasticity, and spatial dependence. Additionally, it is applicable regardless of short or long periods (Ahmad et al., 2020). Furthermore, the study used the two-step system generalized method of moments (system-GMM) for the main estimations. The system-GMM was used because of its advantages over the D-K method. For example, the GMM is capable of overcoming any potential endogeneity in the model. It also helps to estimate the model in a dynamic form. Finally, it is consistent when N>T, as in this study's case. The system-GMM estimates are diagnosed with the Hansen (1982) test for instrument validity and the Arellano-Bond test for second-order serial correlations to ensure efficient results. The Hansen and Arellano-Bond tests have the null hypotheses of valid instruments and no second-order serial correlation, respectively. Based on the advantages of the system-GMM, several studies, including those by Ibrahim & Law (2016), Asongu & Odhiambo (2021), and Ibrahim & Ajide (2022a), have utilized this method to examine the relationship between trade and the environment. As a result, the system-GMM is used for the primary analysis in this study.

The system-GMM specification of equation (3) is expressed in equation (4).

$$\begin{aligned} lnED_{it} - lnED_{it-1} = {} & \delta_0 (lnED_{it-1} - lnED_{it-2}) + \boldsymbol{\delta}' (\boldsymbol{lnX_{it}} - \boldsymbol{lnX_{it-1}}) \\ & + (\gamma_t - \gamma_{t-1}) + (\varepsilon_{it} - \varepsilon_{t-1}) \end{aligned} \tag{4}$$

Where all variables are as defined already. $\boldsymbol{X_{it}}$ represents a vector of sample variables as in Eqs. ((1)–(3)). It must be noted that equation (4) is estimated three times to assess the role of PIES with the total effect of international trade and the specific effects of exports and imports on environmental degradation. The research first estimates the model with the interaction between PIES and trade openness for the overall effect of trade on the environment, whereas in the second and third models, the study estimates the effect of the interaction between exports and PIES and imports and PIES on environmental degradation, respectively. This helps to assess whether there exists a dissimilar impact of exports and imports on the environment.

From Eqs. (3) and (4), the study noticed that the true or actual effect of international trade (all measures) cannot be assessed using coefficients of the trade variables. This is because the actual effect in equations (3 and 4) can be derived through the marginal effects $\left[\frac{\partial lnED_{it}}{\partial IT_{it}} = \delta_1 + \delta_3 PIES\right]$. As a result, this work followed Brambor et al. (2006) to estimate the marginal effects for the true effect of international trade measures.

Finally, the Dumitrescu & Hurlin (DH) (2012) causality test was employed to ascertain the causal relationship between environmental degradation and the variables, particularly, the causal relationship between trade openness, exports, imports, PIES, and environmental degradation. The D-H causality test also accounts for heterogeneity in slope parameters and cross-sectional dependence (Dumitrescu & Hurlin, 2012).

3.3. Data and variable description

The empirical estimations are based on data from a sample of 24 SSA countries (see appendix) from 2005 to 2020. The study period is influenced by PIES data availability, which remains a key variable in this study. Although numerous developing countries in SSA possess abundant natural resources and engage in trade integration with other economies, the study's focus on 24 SSA countries was significantly influenced by the availability of PIES data. Unfortunately, this data is not available for the majority of SSA countries, and many other countries in the region have a significant number of missing values for PIES. As a result, the availability of PIES, which is a crucial variable in this study, restricts the sample to only 24 SSA countries. The variables used for the study include CO_2 emissions (a proxy for environmental degradation), international trade (measured by trade openness, exports and imports), PIES, foreign direct investment, renewable energy consumption, economic growth, urbanization, and industrialization. The choice of these variables for the study is influenced by the STIRPAT model and the previous studies (Acheampong et al., 2019; Zheng et al., 2021; Ibrahim & Ajide, 2022b). Data for all variables were extracted from World Development Indicators (WDI, 2022). The study provides in Table A2 (see appendix) the complete description of the variables.

Table 1 contains the descriptive statistics of the variables in this study. From Table 1, it is revealed that the average CO_2 emissions (metric tons per capita) in SSA is about 0.36. The average value appears relatively lower, yet its harmful effect on the environment makes it a concern. Trade openness, exports, and imports were shown to have an average value of 58.41%, 23.10%, and 34.41%, respectively. The trade openness average value indicates how SSA integrates with the rest of the world for trading activities. Also, the average value of imports shows that SSA economies import more than they export.

PIES is revealed to have an average value of 3.17, which is below the median value of 3.5. The indication is that the strength of policy and institutions towards environmental sustainability in SSA is just about average considering that PIES ranges from 1 (indicating low) to 6 (indicating high) policies for environmental sustainability. Concerning other variables, this study observed that FDI, renewable energy consumption, economic growth, urbanization and industrialization have an average value of 4.08%, 72.21%, 1171.52 dollars, 37.49%, and 22.10%, respectively.

Fig. 1 illustrates the trends in CO_2 emissions, trade (imports and exports), and PIES in SSA from 2005 to 2020. During this period, CO_2 emissions followed an upward trajectory, increasing from roughly 612,882.45 kt in 2005 to almost 833713.85 kt by 2019. On average, total trade in SSA has shown a consistent rise over the study period but with some fluctuations. Further, the study noticed a consistent rise in SSA imports than exports, especially after 2010, indicating a growing volume of goods being imported to SSA. However, both exports and imports exhibited a gradually increasing trend, with some fluctuations. This increase in imports suggests that there is a rising demand for foreign goods in SSA. The PIES index has consistently risen over the years, indicating a strengthening of environmental policies and institutions aimed at promoting sustainability in the region.

This upward trend in CO_2 emissions appears to be positively correlated with the increase in trade, including both exports and imports. This suggests that as SSA engages more in international trade, the associated industrial activities, transportation, and energy consumption likely contribute to higher CO_2 emissions. For instance, increased exports often involve energy-intensive production processes, particularly in industries such as mining and manufacturing, which are significant in SSA. The expansion in exports can thus lead to higher emissions due to increased production. Imports can contribute to emissions both directly and indirectly. The direct impact comes from the transportation of goods into the region, while the indirect impact involves the consumption of imported goods that may require further processing or the use of energy. The rising trend in PIES reflects an increasing recognition of the need for environmental sustainability. Thus, PIES can play a crucial role in mitigating the negative environmental impacts of international trade. The rising trend of PIES in SSA provides empirical justification to assess its mitigating role on the environmental impact of trade in SSA.

Table 1
Descriptive statistics.

Variable (s)	Observation	Mean	Standard Dev.	Minimum	Maximum
CO_2	384	0.362	0.309	0.020	1.461
TO	384	58.411	25.593	0.785	148.587
EX	384	23.992	13.379	0.436	77.464
IM	384	34.419	14.296	0.349	85.778
PIES	384	3.174	0.553	2	4.5
FDI	384	4.084	5.450	−11.199	39.811
RE	384	72.210	17.836	2.78	96.01
EG	384	1171.52	723.488	270.658	3482.448
URB	384	37.494	14.483	9.375	67.829
IND	384	22.102	9.774	4.556	66.179

Note: CO_2, TO, EX, IM, PIES, FDI, RE, EG, URB, and IND represent carbon emissions (a measure of environmental degradation), trade openness, exports, imports, policy and institutions for environmental sustainability, foreign direct investment, renewable energy consumption, economic growth, urbanization, and industrialization, respectively.

4. Results and analysis

This section is centered on the analysis of the estimation results. The study begins with cross-sectional dependency (CD) and thereafter discusses the unit root results. Lastly, the findings from the Driscoll-Kraay (D-K) standard error estimation (baseline), the system-GMM, and D-H causality results are discussed.

4.1. Cross-sectional dependency (CD) results

The results of the CD test are reported in Table 2. From the table, the study could not reject the null of cross-sectional independence in both the Pesaran (2004) and Pesaran (2015) tests. Thus, there is no cross-country correlation in this study.

4.2. Unit root test results

After confirmation of no CD, the stationarity test of the variables was performed, and the results are presented in Table 3.

The results for the various tests (H-T and IPS) of unit roots are reported in Table 3. It is evident from the table that although all the variables exhibit unit roots at levels, the null hypothesis of the existence of unit roots is rejected for all the variables after the first difference across the various tests. Thus, the study concludes that all variables are stationary at the first difference [$I(1)$]. Since the stationarity of the variables has been established, the study proceeds with the estimations of the empirical model.

4.3. D-K standard error estimation (Baseline results)

To establish the role of PIES in the relationship between total trade, exports, imports, and environmental degradation, the study begins with the baseline results. This study does so for comparison purposes, especially for the variables of interest (trade openness, exports, imports, and PIES). The D-K estimation results are shown in Table 4. Columns (1, 2, and 3) denote the models with trade openness, exports, and imports as a measure of international trade, respectively.

Focusing on the variables of interest, the study found in Table 4 that the unconditional (without interaction) impacts of total trade (trade openness) and imports reduce environmental degradation whereas that of exports induces environmental degradation though these effects are insignificant. Given that the actual effect of total trade, exports, and imports is based on marginal effects,[9] the baseline marginal effects of total trade, exports, and imports on environmental degradation were estimated and the results are reported in Table 5. This study observed from Table 5 that improvement in SSA policy and institutions for environmental sustainability at the 25th percentile significantly complement total trade, exports, and imports to promote environmental degradation by about 0.20%, 0.21%, and 0.16% in columns (1, 2, and 3), respectively. However, at the highest percentile levels (75%-99%), PIES

[9] This is as a result of the introduction of the interaction term in the estimation models. Therefore, the actual effect of trade is $\frac{\partial lnED_{it}}{\partial IT_{it}} = \delta_1 + \delta_3 PIES$ but not the coefficient of TO, EX or IM.

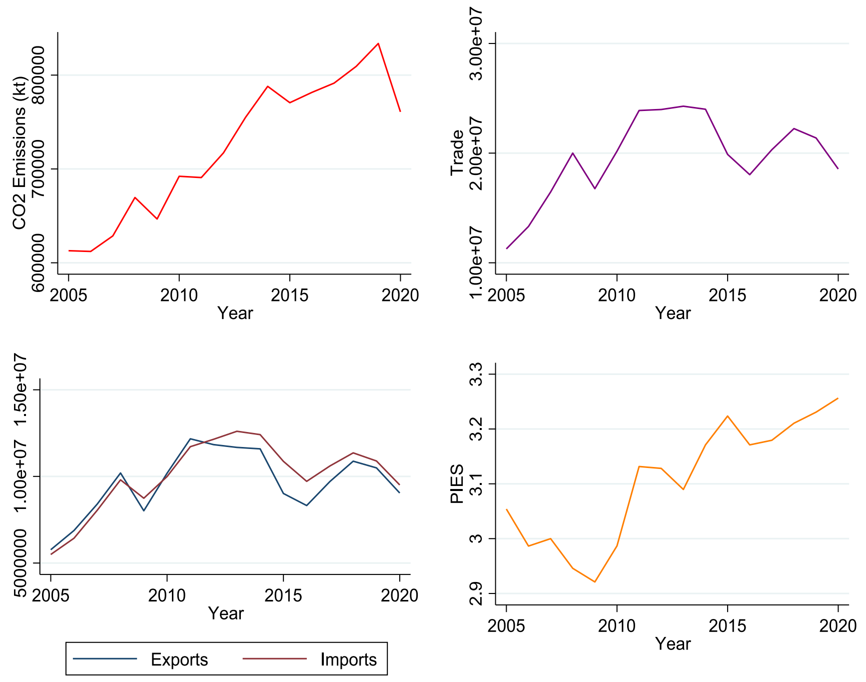

Fig. 1. Trends in CO_2 emissions, trade, exports, imports, and PIES in SSA from 2005 to 2020. Note: CO_2 emissions are measured in kilotonnes, while trade, exports, and imports are expressed in millions (current US$). The PIES index ranges from 1, indicating low PIES, to 6, signifying high PIES.

Table 2
Cross-sectional dependence (CD) results.

	Pesaran (2004) CD		Pesaran (2015) CD	
	CD test	P-value	CD test	P-value
Model 1	−0.01	0.990	−0.005	0.996
Model 2	−0.36	0.716	−0.736	0.462
Model 3	0.34	0.732	−0.723	0.470

Note: Pesaran (2004) CD has the null hypothesis of cross-section independence against cross-section dependence whereas Pesaran (2015) CD has the null hypothesis of errors are weakly cross-sectional dependent against strong cross-sectional dependent.

Table 3
Panel unit root test results.

	Harris-Tzavalis (H-T)		IPS	
Variable(s)	*I*(0)	*I*(1)	*I*(0)	*I*(1)
CO_2	0.789	−0.003***	−1.359	−3.010***
TO	0.683***	−0.132***	−1.643	−3.010***
EX	0.662***	−0.142***	−1.525	−2.581***
IM	0.577***	−0.179***	−1.623	−3.389***
PIES	0.828	−0.051***	−1.410	−2.948***
FDI	0.218***	−0.454***	−2.373***	−3.614***
RE	0.886	0.011***	−1.140	−2.822***
EG	0.885	0.214***	−1.219	−1.915**
URB	0.999	0.153***	−2.471***	−0.693
IND	0.747**	−0.005***	−1.607	−2.795***

Note: CO_2, TO, EX, IM, PIES, FDI, RE, EG, URB, and IND represent carbon emissions (a measure of environmental degradation), trade openness, exports, imports, policy and institutions for environmental sustainability, foreign direct investment, renewable energy consumption, economic growth, urbanization, and industrialization, respectively. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

complements total trade, exports, and imports to reduce environmental degradation by about 0.27%, 0.14%, and 0.30% in columns (1, 2, and 3), respectively. This is an indication that if PIES in SSA is strengthened and remains effective at the highest level, then international trade (total trade, exports, and imports) could ensure environmental quality.

Table 4
Baseline impact of trade, exports, and imports on ED.

Variable(s)	(1)	(2)	(3)
TO	−0.021(0.041)		
EX		0.046(0.050)	
IM			−0.055(0.053)
PIES	0.042(0.046)	0.049(0.047)	0.041(0.044)
TO*PIES	−0.463*** (0.093)		
EX*PIES		−0.348*** (0.061)	
IM*PIES			−0.468**(0.138)
FDI	0.0003(0.004)	−0.002(0.004)	0.002(0.005)
lnRE	−0.315*** (0.025)	−0.318*** (0.023)	−0.308*** (0.026)
lnEG	0.720***(0.028)	0.715***(0.032)	0.731***(0.028)
lnURB	0.702***(0.087)	0.723***(0.089)	0.695***(0.087)
lnIND	0.362***(0.034)	0.370***(0.029)	0.349***(0.041)
Constant	−8.568*** (0.350)	−8.610*** (0.312)	−8.616*** (0.376)
No. observations	384	384	384
R-square	0.873	0.872	0.874
F-statistics (p-value)	13389.51 (0.000)	28792.64 (0.000)	17636.29 (0.000)

Note: Columns 1, 2 and 3 denote model with trade openness, exports, and imports as a measure of trade, respectively. CO_2, TO, EX, IM, PIES, FDI, RE, EG, URB and IND represent carbon emissions (a measure for environmental degradation), trade openness, exports, imports, policy and institutions for environmental sustainability, foreign direct investment, renewable energy consumption, economic growth, urbanization, and industrialization, respectively. The TO*PIES, EX*PIES, and IM*PIES are the interactions between trade openness, exports, imports and policy and institutions for environmental sustainability, respectively. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

4.4. System-GMM estimation (Main results)

Since the baseline model does not account for individual heterogeneity and potential endogeneity, the system-GMM, which overcomes such potential problems, was used for the main analysis to ensure

Table 5
Baseline marginal effects of trade, exports and imports on ED.

Percentiles	Percentiles values	(1)	(2)	(3)
25 %	−0.468	0.196*** (0.031)	0.209*** (0.043)	0.164*** (0.029)
50 %	0.032	−0.036 (0.043)	0.035(0.051)	−0.070 (0.057)
75 %	0.532	−0.268** (0.084)	−0.139* (0.072)	−0.304** (0.124)
99 %	0.532	−0.268** (0.084)	−0.139* (0.072)	−0.304** (0.124)

Note: Columns 1, 2 and 3 denote model with trade openness, exports, and imports as a measure of trade. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

consistent and efficient results. The results and marginal effects are presented in Tables 6 and 7, respectively. Again, columns (1, 2, and 3) denote the models with trade openness, exports, and imports as a measure of trade, respectively.

The results from Table 6 reveal that previous emissions (CO_2) significantly contribute to present emission levels by about 0.40%, 0.55%, and 0.34% in columns (1, 2, and 3), respectively. This implies that SSA emissions exhibit no sign of convergence as previous emissions

Table 6
Impact of trade, exports and imports on ED (system-GMM).

Variable(s)	(1)	(2)	(3)
$lnCO_{2t-1}$	0.404*** (0.140)	0.550*** (0.127)	0.337* (0.182)
TO	−0.148** (0.054)		
EX		−0.061 (0.050)	
IM			−0.273*** (0.072)
PIES	0.113 (0.123)	0.025 (0.110)	0.175 (0.135)
TO*PIES	−0.143* (0.071)		
EX*PIES		−0.050 (0.053)	
IM*PIES			−0.187* (0.093)
FDI	0.003*** (0.001)	0.002 (0.001)	0.005*** (0.001)
lnRE	−0.178** (0.073)	−0.186** (0.068)	−0.173* (0.090)
lnEG	0.445*** (0.110)	0.339*** (0.102)	0.504*** (0.139)
lnURB	0.344*** (0.094)	0.245*** (0.084)	0.376*** (0.129)
lnIND	0.247*** (0.053)	0.167*** (0.052)	0.258*** (0.058)
Constant	−5.061*** (1.257)	−3.514*** (1.173)	−5.741*** (1.587)
Fixed effect	Yes	Yes	Yes
No. observations	360	360	360
No. groups	24	24	24
No. instruments	22	22	22
AR2 (p-value)	−0.837 (0.403)	−0.092 (0.927)	−1.506 (0.132)
Hansen (p-value)	10.10 (0.258)	12.37 (0.136)	6.94 (0.544)

Note: Columns 1, 2 and 3 denote model with trade openness, exports, and imports as a measure of trade, respectively. CO_2, TO, EX, IM, PIES, FDI, RE, EG, URB and IND represent carbon emissions (a measure for environmental degradation), trade openness, exports, imports, policy and institutions for environmental sustainability, foreign direct investment, renewable energy consumption, economic growth, urbanization, and industrialization, respectively. The TO*PIES, EX*PIES, and IM*PIES are the interactions between trade openness, exports, imports and policy and institutions for environmental sustainability, respectively. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 7
Marginal effects of trade, exports and imports on ED (system-GMM).

Percentiles	Percentiles values	(1)	(2)	(3)
25 %	−0.468	−0.081(0.050)	−0.037 (0.055)	−0.185*** (0.063)
50 %	0.032	−0.153** (0.055)	−0.062 (0.051)	−0.279*** (0.073)
75 %	0.532	−0.224*** (0.078)	−0.087 (0.059)	−0.372*** (0.105)
99 %	0.532	−0.224*** (0.078)	−0.087 (0.059)	−0.372*** (0.105)

Note: Columns 1, 2 and 3 denote model with trade openness, exports, and imports as a measure of trade, respectively. Standard errors in parentheses. ** $p < 0.05$, *** $p < 0.01$.

contribute to present environmental degradation. Ibrahim & Law (2016) and Acheampong & Dzator (2020) reported similar outcomes for SSA. Turning to the unconditional impacts of total trade, exports, and imports, the study observed that the unconditional impact of total trade (trade openness), exports, and imports reduces environmental degradation. However, the impact of exports was insignificant (column 2). Focusing on the marginal effects (the actual impacts) in Table 7, the study observed that at all percentile levels (25%-99%), improvement in policy and institutions for environmental sustainability complements total trade, exports, and imports in SSA to enhanced environmental sustainability by reducing the measure of environmental degradation although the effect of exports (all percentile) is insignificant.

Specifically, the results in Table 7 (column 1) indicate that if PIES is improved or at its mean, then a 1 percentage point increase in trade openness (total trade) is associated with 0.15% and 0.22% reduction in environmental degradation at the 50th-99th percentiles, respectively, ceteris paribus. Concerning imports (column 3), the results reveal that for an improvement in PIES, a 1 percentage point increase in SSA imports of goods and services significantly induces a reduction in environmental degradation by about 0.19%, 0.28%, and 0.37% at the 25th-99th percentiles, respectively, holding other variables constant.

Again, the study observed in Table 7 that the rate at which PIES complements total trade, exports, and imports to reduce environmental degradation increases from the lowest to the highest percentiles. This suggests that strengthening PIES in SSA economies can have a significant impact on complementing trade, exports, and imports, thereby enhancing environmental quality. Furthermore, if environmental sustainability policies and institutions in SSA are improved and enforced at the highest level, the benefits of green technology resulting from international trade can be maximized, leading to a sustainable environment in the region. Hence, effective environmental regulations and institutional frameworks can enhance the benefits of trade, such as access to cleaner technologies and economic growth. Therefore, international trade can promote environmental quality when combined with strong policies and institutions. However, the limited impact of exports indicates the need for SSA countries to focus on importing environmentally friendly goods and reevaluating their export strategies to encourage sustainable practices. These findings align with the notion that policies and institutions play a crucial role in promoting sustainable practices in trade and economic activities, which can result in positive outcomes for the environment in the region. The results also suggest that international trade alone is insufficient for ensuring a sustainable environment without effective policies and institutions for environmental sustainability. Consequently, the findings imply that regardless of whether SSA countries focus on exports or imports, trade can ensure environmental quality provided that PIES is effectively improved.

The results are consistent with the findings of Ibrahim & Law (2016) in which institutions complement trade to induce environmental quality. But the results contradict those of Ibrahim & Ajide (2022b) who found that trade facilitation degrades the environment. However, these studies use political institutions (such as the rule of law, government effectiveness, and others) instead of PIES. Besides, these studies do not complement exports and imports with institutions.

Moving to the control variables in Table 6, the results reveal that foreign direct investment (significant in columns 1 and 3), economic growth, urbanization, and industrialization promote environmental degradation. However, renewable energy consumption tends to reduce environmental degradation. Particularly, the coefficient of FDI indicates that for a 1 percentage point increase in FDI, environmental degradation will increase by about 0.03% and 0.05% in columns 1 and 3, respectively, holding all covariates constant. This outcome could imply that FDI inflows to SSA economies fail to implement friendly environmental practices, possibly due to the high level of corruption in SSA. Therefore, their activities result in higher emissions and hence environmental degradation. Studies (Asongu & Odhiambo, 2021; Okelele et al., 2022) have provided similar results. Contrary to the result of the FDI, renewable energy in columns (1, 2, and3) was revealed to have a reduction of 0.18%, 0.19%, and 0.17% in environmental degradation for a 1% increase in renewable energy consumption, respectively, with other variables kept constant. This outcome could be associated with the fact that the negative consequences of environmental degradation force SSA economies to adapt to clean energy, such as renewable energy, which has relatively little or no hazardous effect on the environment. This result is in line with Iheonu et al. (2021) who argue that renewable energy reduces CO_2 emissions.

Furthermore, economic growth was observed to increase environmental degradation by 0.45%, 0.34%, and 0.38% in columns (1, 2, and 3), respectively, ceteris paribus. The outcome could be attributed to the fact that the quest of SSA to achieve economic growth and development tends to instigate macroeconomic policies that ensure growth and development at the expense of the environment. The finding corroborates that of Wang & Dong (2019) and Ibrahim & Ajide (2022b). Furthermore, this study noted that an increase in urbanization (industrialization) induces an increase in environmental degradation by 0.34%, 0.25%, and 0.38% (0.25%, 0.17%, and 0.26%) in columns (1, 2, and 3), respectively. The outcome of industrialization points to the fact that as industrialization increases, most industries tend to engage in activities that require more energy consumption, and this generates higher emissions. This effect is consistent with Zheng et al. (2021) who report that industrialization causes CO_2 emissions.

4.5. D-H causality results

After establishing the complementing role of PIES in the effect of trade openness (total trade), exports, and imports on an environment, a causality analysis was performed because the causal association could influence policy implementation. The D-H result is shown in Table 8.

Table 8
D-H causality test results.

Variable(s)	W-bar	Z-bar	P-value
$lnCO_2 \Leftarrow lnTO$	2.335	4.632	0.000
$lnTO \Leftarrow lnCO_2$	2.707	5.912	0.000
$lnCO_2 \Leftarrow lnEX$	1.806	2.793	0.005
$lnEX \Leftarrow lnCO_2$	3.354	8.156	0.000
$lnCO_2 \Leftarrow lnIM$	2.632	5.652	0.000
$lnIM \Leftarrow lnCO_2$	2.745	6.046	0.000
$lnCO_2 \Leftarrow lnPIES$	1.325	1.127	0.256
$lnPIES \Leftarrow lnCO_2$	1.876	3.034	0.002
$lnCO_2 \Leftarrow FDI$	1.668	2.313	0.021
$FDI \Leftarrow lnCO_2$	2.021	3.538	0.000
$lnCO_2 \Leftarrow lnRE$	1.231	0.799	0.424
$lnRE \Leftarrow lnCO_2$	1.524	1.816	0.069
$lnCO_2 \Leftarrow lnEG$	2.414	4.898	0.000
$lnEG \Leftarrow lnCO_2$	1.401	1.388	0.165
$lnCO_2 \Leftarrow lnURB$	3.402	8.322	0.000
$lnURB \Leftarrow lnCO_2$	3.579	8.935	0.000
$lnCO_2 \Leftarrow lnIND$	1.906	3.138	0.002
$lnIND \Leftarrow lnCO_2$	2.795	6.217	0.000

Note: The null hypothesis of $A \nLeftarrow B$ implies B does not Granger-cause A.

Table 8 shows that total trade, exports, and imports have a bidirectional association with environmental degradation (CO_2). The implication is that trade and CO_2 emissions can influence each other. This is plausible because trade through the production and transportation of goods and services could increase the emission level. Conversely, economies with higher emissions levels are likely to engage in trade to access advanced technologies to limit emission levels. Thus, the observed causality between trade and CO_2 emissions in SSA can be attributed to the region's reliance on resource-intensive exports, energy consumption from trade-related activities, and the import of cleaner technologies to manage emissions. Additionally, higher emissions can drive regulatory responses and participation in international agreements, influencing trade patterns. Iheonu et al. (2021) also reported the existence of bidirectional causality between trade and CO_2 emissions. The results again show existence of a unidirectional relationship from CO_2 emissions to PIES. The unidirectional causality from CO_2 emissions to PIES suggests that higher emission levels necessitate robust PIES in a given economy to instigate stronger regulations and policy interventions for a good environment in SSA.

Furthermore, the study observed that FDI, urbanization, and industrialization have bidirectional causality with CO_2 emissions. However, the study noted a unidirectional causality from economic growth (CO_2 emissions) to CO_2 emissions (renewable energy consumption). These observed causalities can be attributed to the fact that FDI can lead to increased CO_2 emissions as foreign companies may exploit less stringent environmental regulations in host countries, leading to higher pollution. Conversely, countries with higher CO_2 emissions might attract FDI aimed at utilizing green energy sources or investing in technologies to mitigate emissions and improve environmental standards. Urbanization also drives higher CO_2 emissions through increased energy consumption, transportation, and industrial activities associated with urban growth. However, higher emissions, in turn, can influence urban planning and policies, leading to the adoption of greener technologies and infrastructure to manage and reduce urban pollution. Furthermore, industrialization typically increases CO_2 emissions due to the expansion of manufacturing and production activities that rely on fossil fuels, but higher emissions can prompt regulatory changes and technological innovations aimed at reducing industrial pollution, thus affecting the nature and extent of industrial activities. The unidirectional causality from economic growth to CO_2 and CO_2 to renewable energy consumption means that economic growth in SSA initially leads to higher CO_2 emissions as increased production and consumption demand more energy, often from fossil fuels. Over time, as economies grow, they tend to invest more in renewable energy sources to mitigate these emissions, driving a shift towards cleaner energy consumption.

5. Concluding remarks and implications

Concerned about the potential impact of international trade on the environment, this study examined the role of policies and institutions for environmental sustainability (PIES) in the relationship between total trade (trade openness), exports, imports, and environmental degradation in 24 SSA countries. Concerning the estimations, the study used the D-K standard error regression method, the system-GMM, and the D-H causality test for the investigation from 2005 to 2020. The results show that PIES significantly complements the overall impact of trade (trade openness) to reduce environmental degradation. Again, the specific effect of exports and imports on environmental degradation was revealed to reduce environmental degradation when complemented with PIES. In addition, the study noted that FDI, economic growth, urbanization, and industrialization significantly promote environmental degradation. In contrast, the effect of renewable energy consumption reduces environmental degradation. Furthermore, the causality results revealed evidence of a bidirectional relationship between total trade, exports, imports, and environmental degradation in SSA. Based on these findings, the study concludes that effective policies and institutions for environmental sustainability complement international trade (trade openness, exports, and imports) to foster environmental sustainability in SSA. The study further concludes that SSA exports and imports do not have different impacts on the environment.

The implication of this research is that whether SSA economies focus on increasing exports or imports of goods and services, it is crucial to implement strict policies and institutions that promote environmental sustainability. This will enable the beneficial effects of trade on the environment to be enhanced when robust environmental policies and institutions are in place. Therefore, this study recommends that environmental institutions in the SSA economies enforce strict regulations on the production and transportation of traded goods and services. This will ensure that any policies or initiatives related to exports or imports are assessed or reviewed by environmental officials before implementation, thereby promoting green initiatives that can improve environmental quality. The specific effect of exports and imports on environmental degradation was found to reduce environmental degradation when complemented with PIES. This implies that when environmental policies and institutions are strong, the negative environmental impacts of increased trade can be mitigated, leading to a net positive outcome for environmental quality. For instance, stringent regulations on emissions and waste management during production can ensure that goods produced for export are environmentally friendly. Similarly, import regulations can prevent the influx of environmentally harmful goods and promote the import of sustainable products in SSA.

To achieve the goal of robust PIES in SSA, it is crucial to eliminate corruption from environmental institutions. Corruption can weaken the effectiveness of these institutions by compromising the enforcement of environmental regulations, allowing environmentally harmful practices to persist. Therefore, enhancing the integrity and transparency of environmental institutions is critical in SSA. Strategies such as increasing accountability, promoting transparency in decision-making processes, and fostering civil society involvement in environmental governance can help reduce corruption and improve the efficacy of environmental policies. By adopting these measures, SSA economies can achieve environmental sustainability and enhance the positive effects of trade openness on the environment. This integrated approach can lead to a decrease in environmental degradation and encourage a sustainable path of economic development. The study highlights the significance of a holistic strategy that combines trade policies with strong environmental governance to attain long-term sustainability goals.

Although this study has considered the role of PIES in the relationship between trade, exports, imports, and environmental degradation, the study did not account for whether differences in PIES between SSA economies matter. As a result, this study recommends that future studies consider the heterogeneity analysis of PIES in the trade-environment relationship in SSA and beyond.

Author contributions

All authors, Desmond Mbe-Nyire Mpuure, Emmanuel Duodu, Adamu Braimah Abille, and Eric Atanga Ayamga contributed to the conception and design of the study. All authors wrote the first draft of the manuscript. All authors commented on previous versions of the manuscript and finally read and approved the final manuscript.

Funding

This article did not receive any funding.

CRediT authorship contribution statement

Desmond Mbe-Nyire Mpuure: Writing – review & editing, Writing – original draft, Formal analysis, Data curation, Conceptualization. **Emmanuel Duodu:** Writing – review & editing, Writing – original draft, Formal analysis, Data curation, Conceptualization. **Adamu Braimah Abille:** Writing – review & editing, Writing – original draft, Formal analysis, Data curation, Conceptualization. **Eric Atanga Ayamga:** Writing – review & editing, Writing – original draft, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix

Table A1
Description of variable(s).

Variable(s)	Measurement	Definition	Source
Environmental degradation (ED)	CO_2 emissions (metric tons per capita)	Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.	WDI, 2022
Trade openness (TO)	Trade (% of GDP)	Trade is the sum of exports and imports of goods and services measured as a share of gross domestic product.	WDI, 2022
Exports (EX)	Exports of goods and services (% of GDP)	Exports of goods and services represent the value of all goods and other market services provided to the rest of the world.	WDI, 2022
Imports (IM)	Imports of goods and services (% of GDP)	Imports of goods and services represent the value of all goods and other market services received from the rest of the world.	WDI, 2022
Policy and institutions for environmental sustainability (PIES)	Policy and institutions for environmental sustainability rating (1 = weak to 6 = strong)	Measures the extent to which environmental policies promote the protection and sustainable use of natural resources and the management of pollution.	WDI, 2022
Foreign direct investment (FDI)	Net inflows of foreign direct investment (% of GDP)	Foreign direct investment are the net inflows of investment to acquire a lasting management interest in an enterprise operating in an economy other than that of the investor.	WDI, 2022
Renewable energy (RE)	Renewable energy consumption (% of total final energy consumption)	Renewable energy consumption is the share of renewable(s) energy in total final energy consumption.	WDI, 2022

(*continued on next page*)

Table A1 (*continued*)

Variable(s)	Measurement	Definition	Source
Economic growth (EG)	GDP per capita (constant 2015 US$)	GDP per capita is gross domestic product divided by midyear population.	WDI, 2022
Urbanization (URB)	Urban population (% of total population)	Urban population is the number of people living in urban areas as defined by national statistical offices.	WDI, 2022
Industrialization (IND)	Industry value added (% of GDP)	It comprises value added in mining, manufacturing, construction, electricity, water, and gas.	WDI, 2022

Table A2
Selected SSA countries.

Burkina Faso	Congo, Republic	Guinea-Bissau	Niger	Tanzania
Burundi	Cote d'Ivoire	Kenya	Nigeria	Togo
Cabo Verde	Gambia	Madagascar	Rwanda	Uganda
Cameroon	Ghana	Mali	Sierra Leone	Zimbabwe
Comoros	Guinea	Mauritania	Sudan	

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