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Global shipping and climate change impacts in Africa: the role of international trade

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Abstract

This paper examines the interacting effect of global shipping and trade on climate change in Africa using data on 31 countries for the period 2006–2016. We employ the system generalized method of moments estimation technique for our analysis. The results reveal that, in both the short run and long run, global shipping and trade contribute significantly to climate change in African countries. Furthermore, we document that the impact of shipping on climate change become larger through the aggregate trade channel. Based on these outcomes, policies designed to reduce emissions from global shipping are important in mitigating the menaces of climate change in Africa.

Keywords: Trade, Global shipping, Climate change, System-GMM, Africa

Introduction

In recent times, there have been mammoth efforts towards reducing climate change worldwide due to its negative repercussions. Africa is not an exception in the climate change battle. This is so because an increase in climate change has detrimental effects on human and natural habitats, ecosystems, water bodies, agriculture, drought, population displacement, food security, etc. (Chebbi et al. 2011; Sislian et al. 2016; Mahmood et al. 2019; United Nations Conference on Trade and Development [UNCTAD] 2020; Can et al. 2021). As a result, several policies have been embarked upon globally by stakeholders and international agencies towards combating climate change. Amongst the policies include the Paris Agreement International Treaty on Climate Change [IPCC] (2014), the United Nations Framework Convention on Climate Change [UNFCCC] programmes, the African Center on Climate policy, and the AfDB (2010) Africa Climate for Development programmes.

Notwithstanding these programmes, recent reports by the United Nations (2020) on climate change reveal an increasing trend and intense economic impact of climate change on the African continent, thereby making it the most vulnerable continent to climate change in the world. This makes the continent's efforts in achieving the Sustainable Development Goals unlikely. According to the African Development Bank report on climate change in Africa [AfDBCCA] (2022), African countries are adversely affected by climate change. The trends in climate change in Africa show that these impacts are likely to continue and intensify in the coming years. According to the Intergovernmental

Panel on Climate Change (IPCC) (2014), temperatures in Africa are projected to increase by more than the global average, with an increase of up to 3.9 °C by the end of the century. This warming trend is expected to lead to more frequent and intense heatwaves, droughts, and flooding, which will have negative impacts on agriculture, water resources, and human health (United Nations Environment Programme 2018). Moreover, rising sea levels and coastal erosion are expected to increase coastal flooding and storms, particularly in low-lying areas such as coastal cities and islands (IPCC 2014).

International trade and shipping are among the factors that could potentially contribute to climate change, especially in developing countries. For instance, an increase in international trade could lead to higher energy consumption and this could lead to an increase in carbon dioxide emission (see Shahbaz et al. 2015; Can et al. 2021), thereby leading to an increase in climate change. In this paper, we examine the extent to which shipping and aggregate trade in goods and services influence climate change in Africa. Climate change-related research is important especially in developing countries in order to aid and guide policies aimed at reducing greenhouse gas emissions. Empirical studies on international trade and climate change in African countries and other continents of the world have clearly demonstrated that international trade has a positive effect on climate change (see: Adams and Acheampong 2019; Acheampong et al. 2020; Chebbi et al. 2011; Mahmood et al. 2019; Ansari et al. 2020). Further, since international trade requires the shipment of goods and services by which ships use fossil fuels, shipping could lead to an increase in climate change via carbon dioxide emissions and the emissions of other greenhouse gases into the atmosphere. Again, given the fact that ships are responsible for the transportation of 80 percent of global trade (in terms of volume), the greenhouse gas emission by ships could significantly contribute to climate change in African countries due to their over-reliance on trade from developed economies (United Nations Conference on Trade and Development [UNCTAD] 2018, and United Nations Economic Commission for Africa [UNECEA] 2016). Carbon dioxide emissions is projected to increase from 60% in the year 2017 to 160% by 2050 if no additional environmental protection measures are taken (Organization of Economic Cooperation Development [OECD] 2018; Liu et al. 2018). Kolieb (2008) notes that the shipping industry is responsible for a significant proportion of climate change problems worldwide. Consequently, this makes shipping a major contributor to climate change despite its significant contribution to economic growth as well as providing an economical and reliable way of moving goods and services via long distances (AfDB 2010; UNCTAD 2018).

In this paper, we argue that the impact of shipping on climate change is largely possible given an increase in international trade. This is because, increasing trade will increase shipping (UNCTAD, 2018), and increasing shipping will increase carbon dioxide emission by ships and this increases climate change (Kolieb 2008; Andersson et al. 2016; Lv et al. 2018; Jagerbrand et al. 2019; Sinanaj 2020). As noted by Kolieb (2008), ships burn the dirtiest fuel among all the transportation modes and hence a continuous increase in shipping will increase the emission of carbon dioxide into the atmosphere. Empirically, while the impact of trade on climate change has been examined in the context of African countries, there is no study in existence that has investigated the impact of shipping on climate change and how an increase in trade can influence the impact of shipping on climate change in African countries, to the best of our knowledge. Therefore, this paper fills the research gap by investigating the direct effects of shipping on climate change in the context of African countries. Secondly, we contribute to the literature by examining the interacting role of trade and shipping, an important step that is missing in the literature. Thirdly, our empirical study also contributes significantly to the literature given that we are able to examine not only the direction of the effect of international trade and shipping on climate change, but the extent of the impact when they are interacted. We postulate that the true impact of shipping on climate change depends on trade, given that increase in trade increases shipping. And as already indicated, increased shipping would increase the emission of carbon dioxide and subsequently increase climate change. We focus on African countries because (i) About 90 percent of merchandise trade to the continents is done through shipment, hence as Africa's maritime sector grows, with increasing marine traffic and cargo volumes through its ports, so does the potential for heavier environmental and social impacts (ii) Africa remains the most vulnerable continent to climate change globally.

The remaining section of the paper is structured as follows. Section "Literature review" focuses on the theoretical and empirical framework. Section "Model specification, data issues, and estimation technique" presents the model specification, data issues, and estimation technique while Section"Results and discussion" focuses on the results and discussion. Finally, Section"Conclusion and policy suggestions" provides the conclusion and policy recommendations.

Literature review

Theoretically, the link between trade and climate change (measured using carbon dioxide emission) could be gleamed from the scale, technique, and composition effects (Shahbaz et al. 2013, 2015; Can et al. 2021). According to the scale effects, increasing trade requires higher levels of energy consumption and this contributes to an increase in carbon dioxide emission. Apart from this, increasing production activities is associated with the expansion of exports and imports and this needs enormous levels of energy consumption, with the consequence being an increase in climate change (Can et al. 2021). However, the technique effect argues that trade opens the door for the importation of efficient technologies for manufacturing by developing economies, thereby limiting pollution activities because of less energy consumption that is required for production. This leads to a decrease in climate change (Shahbaz et al. 2015; Can et al. 2021). The composition effects posit that the transformation of production from agriculture to an industrial sector changes the energy required for production due to production changes and this is likely to increase climate change. Based on the afore and following the scale effects hypothesis for this study, we postulate that increasing trading activities and production activities in the context of African countries will increase climate change and thereby leads to a deterioration of the environment.

Regarding the theories that explain shipping and climate change, we found no theories to the best of our knowledge. However, we try to provide a linkage between shipping and climate change and assess the possible relationship empirically. Although shipping is known to be a reliable means of transportation for moving goods and services worldwide, it contributes significantly to carbon dioxide emissions and greenhouse gases through the emission of fossil fuels by ships, hence contributing to an increase in climate change. Therefore, the present study hypotheses that shipping affects climate change possibly through an increase in trading activities which would increase the amount of fossil fuel burnt by ships and ultimately increase climate change. The literature on shipping and climate change has revealed that huge volumes of shipping are associated with negative environmental effects (Sislian et al. 2016; Andersson et al. 2016; Ceyhun 2014; Lv et al. 2018; Jagerbrand et al. 2019; Sinanaj 2020; Ben-Hakoun et al. 2021).

Regarding empirical studies using data from Africa, Acheampong et al. (2020), Adams and Acheampong (2019), Adams and Klobodu (2018), Adebayo and Odugbesan (2021), Ali (2021), Altinoz and Dogan (2021), Ali et al. (2019), Chebbi et al. (2011), Mahmood et al. (2019) and Kwakwa (2020) used varied estimation technique and found that trade has a positive significant effect on climate change in Africa countries. These studies measured climate change using carbon dioxide emissions while the sum of exports and imports as a percentage of GDP was employed as a proxy for trade. Contrary to the positive effects of climate change that have been revealed in African countries, quite a number of studies have also found trade to have a negative effect on climate change in African countries(see Kwakwa 2021; Abbasi et al. 2020). With respect to studies on shipping on climate change in African countries, to the best of our knowledge, we did not find any study that has examined the effects of shipping on climate change in African countries.

In relation to studies that have examined the nexus between trade and climate change in other part of the world, a large body of empirical studies have found the effects of trade on climate change to be positive. For example, Abbasi et al. (2020), Acheampong et al. (2020), Adebayo and Odugbesan (2021), Ali et al. (2021), Altinoz and Dogan (2021), Ansari et al. (2020), Can et al. (2021), Liu et al. (2018), and Marques and Caefano (2020) used different estimation techniques and datasets and demonstrated that trade effects on climate change are positive.

Concerning studies on shipping and climate change, Andersson et al. (2016), Ceyhun (2014), Franc and Sutto (2014); Chang and Wang (2014), Zhang et al. (2017), Lv et al. (2018), Jagerbrand et al. (2019), Sinanaj (2020), Ben-Hakoun et al. (2021) document a positive impact of shipping on climate change using data from Asian and European countries.

In summary, it is evident that to a large extent, globally, trade affects climate change positively[1] Although no study has been devoted to the effects of shipping on climate change in Africa, it has been established in other parts of the world empirically that shipping effects on climate change are positive. However, what is unknown in the literature on climate change is whether trade increases the impact of shipping on climate change. This study seeks to address this gap in the literature. To this end, this study fills a major research gap by examining the direct effects of shipping on climate change in Africa. Most importantly, we investigate the role played by trade in influencing the impact of shipping on climate change in the context of African countries.

[1] We refer to a positive climate change to mean increase in climate change and a negative climate change indicates a decrease in climate change.

Model specification, data issues, and estimation technique

To investigate the role trade plays in the relationship between shipping and climate change in African countries, the paper specifies Eq. (1) for estimation:

$$CC_{it} = \beta + \delta CC_{it-1} + \alpha SP_{it} + \theta TRD_{it} + \rho(SP_{it} * TRD_{it}) + \omega V_{it} + \mu_i + \gamma_t + \varepsilon_{it} \quad (1)$$

In Eq. (1), $CC, SP, and TRD$ denote climate change, shipping, and trade, respectively. Also, V represents other variables that determine climate change. The first lag of climate change is represented by CC_{it-1}; the coefficient of interest measuring the role played by trade in influencing the impacts of shipping on climate change is represented by the parameter ρ. In addition, μ_i and γ_t denote the country and time-specific effects respectively whiles ε_{it} represents the disturbance term.

It must be stressed that from our model specification, including the interaction effects of shipping and trade changes the way the economic impacts of shipping on climate change are interpreted as noted by Brambor et al. (2006). This is because, according to Brambor et al. (2006), in interactive models, the effects of the explanatory variable on the dependent variable are dependent on some values of the conditional variable. As a result, we posit that the effects of shipping on climate change depend on some values of trade. The implication here is that an increase in shipping will increase (decrease) climate change only in the presence of an increase (decrease) in trade. Therefore, a positive (negative) coefficient of the interaction term is an indication that trade complement shipping to affect climate change positively (negatively). Furthermore, in Eq. (1), the direct impact of shipping and trade variables on climate change are denoted by the parameters α and θ. Such that the parameter α captures the direct effects of a unit increase (decrease) in shipping on climate change when trade is absent. Notwithstanding, in this paper shipping and trade have non-zero values in their measurement and hence it is not plausible to assume a zero value for shipping and trade as argued by Brambor et al. (2006), Sakyi and Egyir (2017), and Egyir et al. (2020). Therefore, Brambor et al. (2006) proposed a meaningful way to interpret the coefficient of the direct effect of shipping and trade. It requires that shipping and trade variables are mean-centered. Accordingly, we follow this approach in this paper by mean-centering trade and shipping variables; such that α indicates the marginal effects of a unit increase (decrease) in shipping on climate change when trade is at its mean. This is essential because, centering provides a logical interpretation of the variables of interest (Brambor et al. 2006; Sakyi and Egyir 2017; Egyir et al. 2020). In assessing the total conditional marginal effects of shipping on climate change, we take the partial differential of climate change with respect to shipping as trade improves and this yield Eq. (2):

$$\frac{\partial CC_{it}}{\partial SP_{it}} = \alpha + \rho * TRD_{it} \quad (2)$$

Data issues

Data on 31 African countries spanning the period 2006–2016 is employed for the analysis.[2] The summary statistics of the variables used for the estimation are presented in

[2] The period of study and data chosen is due to the availability of data on the variables of interest that is climate change, shipping, and trade.

Table 1 Summary statistics of variables

Variables	Obs	Mean	Minimum	Maximum	SD
Climate change	341	1.537	0.026	10.428	2.252
Shipping	341	15.112 [0.000]	1.589 [− 0.531]	61.742 [0.469]	11.113 [0.331]
Trade	341	79.894 [0.000]	20.722 [− 0.510]	311.354 [0.489]	38.146 [0.320]
Population density	341	92.699	2.394	622.400	121.657
Income	341	3171.946	306.528	20,532.950	3862.747
Government spending	341	14.211	5.126	39.451	5.126
Foreign direct investment	341	5.893	− 5.208	103.337	10.975
Quality of institution	341	0.000	− 1.587	1.458	0.816

The values in bracket for shipping and trade are the centered values

Source: Authors

Table 1. Furthermore, the list of countries used for the analysis are found in Table 8 in the Appendix section of the paper.

Climate change, shipping, and trade measures

We use carbon dioxide emission per metric tons as an indicator for climate change. Regarding the measurement of shipping and trade variables, the paper uses the UNCATD liner shipping connectivity index as a proxy for shipping while the summation of exports and imports as a percentage of GDP is used as a measure of trade. Data on climate change and trade are taken from the World Bank World Development Indicators and United Nations Conference on Trade and Development database, respectively. The use of liner shipping connectivity as a proxy for shipping is valid since it captures how a country is connected and integrated into the world's liner shipping connections in terms of maritime connectivity (UNCTAD 2018). The liner shipping connectivity index compiled by UNCTAD ranges from 1 to 100 and above. A higher value implies access to a high capacity and regular global maritime freight transport system and effective participation in international trade. Therefore, the paper argues that as participation in trade increases, it is expected that the emission of greenhouse gases by ships would increase thereby contributing to an increase in climate change.

Control variables

The paper uses Population density (PD), Income (INC), Government spending (GSP), Foreign direct investment (FDI), and quality of institution as control variables (IQI). Population density is measured as people leaving Per sq.km of land area; income is proxied by GDP per capita (constant US dollars); foreign direct investment is measured as foreign direct investment inflows as % of GDP; general government final consumption expenditure as % of GDP is used to denote government spending, and the World Governance indicators namely Control of corruption, Government effectiveness, Political stability and absence of violence, Regulatory quality, Rule of law and Voice and accountability are used as measures of quality of institutions. The source of data on all the control variables is taken from the World Bank World Development Indicators except for the

Table 2 Principal components analysis of quality of institutions index from primary indicators

	Eigen-value	Proportion explained	Primary variables	Eigen-vectors	Correlation coefficients	Bartlett (*p*-value)
Institution	2.241	0.374	Control of corruption	0.404	0.249	
	1.075	0.179	Government effectiveness	0.408	0.239	**0.000**
		0.139	Political stability	0.412	0.922	
		0.125	Regulatory quality	0.348	0.293	
		0.096	Rule of law	0.491	0.394	
		0.087	Voice and accountability	0.372	0.594	

Source: Authors

quality of institution variables that were taken from the World Governance indicators of the World Bank.

Regarding the quality of the institutions, we use the principal components analysis to construct an index from the six primary governance indicators mentioned above and call it an institutional quality index. It can be seen from Table 2 that the index generated is solely based on the two principal components obtained with an eigen value greater than one.[3] It must be noted that, as reported in Table 2, the correlation coefficients show the degree of correlation between the constructed index and the corresponding primary variables used. Also, the number of principal components was selected by the Kaiser criterion of eigenvalue greater than one while the null hypothesis of the Bartlett test of sphericity clearly shows that the variables are not intercorrelated.

In addition, with respect to the issue of multicollinearity among our variables, especially trade and shipping, we conduct a correlation matrix analysis, and the results are reported in the Appendix section Tables 6 and 7. The results of the correlation matrix indicates that the independent variables are not collinear; hence, indicating the absence of multicollinearity (correlation) among our variables.

Estimation technique

It must be emphasized that, due to the dynamic nature of the model specified in Eq. (1), using estimators such as ordinary least square, fixed effects, and random effects will lead to a bias and inconsistent estimate of the parameters (see: Arellano and Bond 1991; Roodman 2009; Sakyi and Egyir 2017; Egyir et al. 2020). Apart from this, the issue of potential endogeneity bias and reverse causality is likely to be encountered when estimating Eq. (1). The issue of endogeneity could arise from the possible feedback effects of climate change and measures of trade, and shipping. Further, the concern of reverse causality is a result of the inclusion of the lagged value of climate change which is likely to be correlated with the unobserved country-specific effects that are absorbed in the disturbance term. There is also the possibility of simultaneity bias, arising among the explanatory variables being studied.

[3] Chen and Woo (2010), and Sakyi et al. (2017) show how to construct an index using the principal component analysis when the primary indicators used have more than one eigen value.

Therefore, to ensure a consistent estimate of the parameters in Eq. (1), we employ the dynamic system Generalized Method of Moments (GMM) estimation technique for the regression analysis (Arellano and Bond 1991; Roodman 2009). We make use of the system-GMM because it can deal with the possible issues that come up when estimating a dynamic relationship by eliminating unobservable individual-specific effects and inherent omitted variable bias. In addition, the number of countries used is greater than the period in this paper (i.e., N > T), hence making the GMM suitable for the empirical analysis.

In assessing the validity of the system-GMM estimator, first, it requires the absence of second-order autocorrelation, and second, it also requires that the internally generated instruments are valid. To address the issue of second-order autocorrelation, we verify that the idiosyncratic error term does not exhibit significant second-order serial correlation in the differences by employing the Arrellano and Bond test for second-order autocorrelation (Arellano and Bond 1991; Roodman 2009). Also, the instruments' validity is verified by employing the Hansen test for over-identification restrictions (Arellano and Bond 1991; Roodman 2009).

Concerning the analysis, the paper provides the short and long-run results of the variables. Apart from the coefficient of the lagged dependent variable that measures the effect of past values of climate change on current values of climate change, all the explanatory variables' coefficients indicate the short-run impact on climate change. In addition to the -short-run results, to aid policy suggestion, the long-run results of the effects of trade and shipping on climate change are also estimated. We compute for the long-run results by dividing each short-run coefficient result by 1 minus the coefficient of the lagged value of the dependent variable as suggested by Papke and Wooldridge (2005). Doing so helps to obtain the long-run coefficients, standard errors, and p-values of the explanatory variables.

Results and discussion

We report and discuss the empirical results obtained in four sub-sections. Sub-Section "Economic interpretation of the direct and interaction effects of shipping and trade on climate change" is devoted to the economic interpretation of the direct and interaction effects of shipping and trade on climate change. Section "Economic interpretation of the control variables" is devoted to the economic interpretation of the control variables. This is followed by the economic interpretation of the marginal effects results as well as the statistical appropriateness of the estimated model. Finally, we situate the findings and discussions to policies in Section "Discussion of findings in line with policies on shipping, trade, and climate change in Africa ".

Economic interpretation of the direct and interaction effects of shipping and trade on climate change

As earlier indicated, the direct and interaction effects of trade and shipping on climate change are discussed in this section. The estimated results are presented in Tables 4 and 5. From the results in Tables 3 and 4, shipping has a direct positive significant effect on climate change in both the short and long-run periods. The effects range from 0.072 to 0.314% which is significant at the 5% level of statistical significance.

Table 3 Short-run estimates of the effect of trade and shipping on climate change

Variable	Coefficient	Standard errors	Prob. Values
CC(-1)	0.769	0.076	0.000
SP	0.072	0.027	0.014
TRD	0.059	0.028	0.047
SP*TRD	0.235	0.111	0.043
lnPD	0.022	0.026	0.415
lnINC	0.293	0.093	0.004
lnGSP	0.029	0.092	0.755
FDI	0.238	0.107	0.034
IQI	− 0.011	0.014	0.463
Constants	− 2.438	0.819	0.006
AR(2)[prob]	0.680		
Hansen[prob]	0.202		
Observations	310		
Number of groups	31		
Number of instruments	26		

Source: Authors

Table 4 Long-run estimates of the effect of trade and shipping on climate change

Variable	Coefficient	Standard errors	Prob. Values
SP	0.314	0.091	0.001
TRD	0.256	0.114	0.024
SP*TRD	1.022	0.614	0.096
lnPD	0.095	0.124	0.444
lnINC	1.272	0.143	0.000
lnGSP	0.126	0.382	0.742
FDI	1.033	0.586	0.078
IQI	− 0.047	0.059	0.436
Constants	− 10.585	0.950	0.000

Source: Authors

This outcome suggests that when trade is at its mean value, an increase in shipping increases climate change in the context of African countries. All things being equal, shipping contributes to increasing climate change in African countries. The implication of these findings could be that since shipping involves the usage of fossil fuels, and ships are noted for burning the dirtiest fuel among all the other modes of transportation (Kolieb 2008), it contributes significantly to climate change by emitting carbon dioxide gas and hence increase in shipping could lead to an increase in climate change. The burning dirty fuel by ships is indeed linked to greenhouse gas emissions, as this type of fuel is high in Sulphur and other pollutants that contribute to air pollution and climate change (International Maritime Organization 2021). According to the International Maritime Organization (2021), shipping emissions are estimated to contribute up to 2.5% of global greenhouse gas emissions, and this is expected to increase in the coming years if no action is taken. Apart from the aforementioned, ships also release several pollutants that contribute to worsening climate change globally (Kolieb 2008; Andersson et al. 2016). Furthermore, shipping can also contribute

Table 5 The marginal effect of shipping on climate change as trade increase

Percentiles	TRD	Coefficient	SE	95% Confidence interval	
Short run: impact of shipping on climate change as trade increases					
5%	− 0.531	− 0.066	0.075	− 0.219	0.087
10%	− 0.511	− 0.066	0.075	− 0.219	0.087
25%	− 0.277	− 0.006	0.049	− 0.107	0.094
50%	0.003	0.067**	0.027	0.012	0.123
75%	0.314	0.133***	0.035	0.060	0.205
90%	0.457	0.166***	0.048	0.069	0.264
95%	0.469	0.169***	0.049	0.070	0.269
Long run: impact of shipping on climate change as trade increase					
5%	− 0.531	− 0.287	0.360	− 0.993	0.419
10%	− 0.511	− 0.267	0.349	− 0.951	0.416
25%	− 0.277	− 0.027	0.217	− 0.453	0.399
50%	0.003	0.292***	0.113	0.071	0.513
75%	0.314	0.577***	0.209	0.166	0.988
90%	0.457	0.723**	0.287	0.159	1.286
95%	0.469	0.735**	0.293	0.159	1.311

*** and ** denote 1% and 5% level of statistical significance respectively; SE and TRD indicates standard errors and trade

Source: Authors

to climate change through other indirect impacts such as the release of greenhouse gases from the production and transport of fuel, and the effects of shipping on ocean acidification and marine ecosystems. Therefore, a continuous increase in the rate of shipping activities will result in an increase in climate change. This finding is in tandem with the studies by Kolieb (2008), Sislian et al. (2016), Andersson et al. (2016), Ceyhun (2014), Chang and Wang (2014), Zhang et al. (2017), Lv et al. (2018), Jagerbrand et al. (2019), Sinanaj (2020), and Ben-Hakoun et al. (2021). These studies show that shipping contributes to an increase in greenhouse gasses which subsequently results in an increase in climate change.

Regarding the effect of trade on climate change, conditional on the mean value of shipping, the results show that the effect of trade on climate change is positive and significant at the 5% level of statistical significance. The coefficient ranges between 0.059 and 0.256% in the -short-run and long-run periods. The magnitude of the coefficients means that a percentage increase in trade leads to a 0.059–0.256% increase in climate change in Africa. The plausible reason for the positive relationship between trade and climate change revealed in this study for African countries could be that some African countries have still not put in place restricted trade structures, and hence their engagement in trade and production activities has not considered advanced and environmentally friendly technologies, and this increases carbon dioxide emission, thus increasing climate change rather than reducing climate change. Also, increased trade can lead to higher greenhouse gas emissions due to increased transport and energy use. For example, the transportation of goods by sea and road can lead to significant emissions, which contribute to global climate change. This can be exacerbated in Africa, where the transportation infrastructure is often inadequate, leading to longer transport times and greater emissions. The outcome aforementioned is in line with similar studies by Chebbi et al. 2011; Fang et al. 2018; Ali et al. 2019; Lv and Xu 2019; Phuc Nguyen et al. 2020).

In relation to the interactive results of trade and shipping (i.e., the role played by trade in increasing the impact of shipping on climate change-the focus of the study), we find the coefficients to be significantly positive. In terms of the economic magnitude of the coefficient, a percentage increase in the extent to which trade complements shipping is associated with a 0.235–1.022% increase in climate change. More significantly, it could be seen that the coefficient is much larger than the direct effect of trade and shipping on climate change. Indeed, this finding points to our arguments that for shipping to worsen climate change it requires an increase in trading activities; such that as trade increases, it increases the emissions of greenhouse gases such as fossil fuels that are emitted by ships into the atmosphere among others in the cause of moving tradable goods from one region to the other thereby increasing climate change. This result also means that the extent to which trade complements shipping is associated with a deterioration in climate change. This is not surprising as it confirms the situation in Africa where due to heavy reliance on imported products, the movements of ships (vessels) into the region are likely to increase greenhouse emissions into the atmosphere thereby contributing to an increase in climate change.

Economic interpretation of the control variables

In Table 3, the coefficient of first lag of climate change is positive and significant at the 1% level. The implication is that a percentage deterioration in the past year's value of climate change hampers the current level of climate change by 0.769%. This outcome is not startling since worsening past values of climate change may negatively affect current climate change.

With respect to the results on income, we found that a 1% increase results in an increase in climate change by 0.293–1.272% in the short and long-run periods. The results support the environmental Kuznets hypothesis and could mean that the increase in the growth pattern of African countries over the years, corresponds with increasing activities that increase carbon dioxide emissions thereby increasing climate change. Chebbi et al. (2011); Fang et al. (2018); and Mahmood et al. (2019) find similar evidence of a positive effect of income on climate change whiles the findings by To et al. (2019) are in contrast. We find that an increase in foreign direct investment worsens climate change in African countries. Specifically, the magnitude of the coefficient reveals that a percentage increase in inflows of foreign direct investment increases climate change by 0.238–1.033% (Tables 3 and 4). This outcome agrees with the theory on Population Haven Hypothesis which postulates that inflows of foreign direct investment are a contributing to climate change in developing economies (Eskeland and Harrison 2003). Thus, since there are less stringent environmental regulations in developing economies, developed economies are more likely to shift the production of their pollution-intensive commodities and when this happens it will likely increase climate change in developing economies as revealed by the findings from the study. The results obtained confirm the studies by Phuc Nguyen et al. (2020); Marques and Caefano (2020); and To et al. (2019) who found a positive relationship between foreign direct investment and climate change.

Our findings also show that population density has a positive but insignificant effect on climate change in African countries. Although insignificant, the coefficient suggests that a percentage increase in population density is associated with a 0.022% and 0.293% increase in climate change in the short-run, and long-run periods. Regarding the quality of institutions, although insignificant, we find that the quality of institutions decreases climate change in African countries with the effect ranging from 0.011 to 0.047% in the short- and long-run periods.

Marginal effects results

As indicated earlier, this section is devoted to the interpretation of the marginal effect results which are reported in Table 5. The focus of this section is the analysis of the role played by trade in influencing the impact of shipping on climate change in Africa. To achieve this, the impact of shipping on climate change is evaluated at some percentile values of trade as shown in Eq. (2). We note that the computed coefficients if statistically significant, shows the percentile level(s) at which trade have complementary effects on the influence of shipping on climate change.

As evident, the short- and long-run results reported in Table 5 reveal that the marginal effect increases as we move upward the percentile scale. This shows that all other things being equal, a continuous increase in trade is crucial for shipping to have its largest impact on climate change in Africa. As indicated in Table 5, these effects are substantial and statistically significant mainly from the 50^{th} percentile upwards. The afore is important for policy implication because, although an increase in trade is essential for the growth of the economy, it leads to worsening climate change through shipping, and hence policy reforms (strong climate change policies) should be incorporated into broad policy schemes by stakeholders.

Concerning the model diagnostics, as stated earlier, the system-GMM estimates require the absence of second-order autocorrelation and the fact that the instruments used should be valid ones (Arellano and Bond 1991; Roodman 2009). As evident (see Table 3), there is not enough evidence to reject the null hypothesis of no second-order autocorrelation. Additionally, the overall validity of the instruments used is confirmed in our estimated model by the Hansen J test. In sum, the diagnostic statistics confirm that the estimates are valid for drawing policy suggestions.

Discussion of findings in line with policies on shipping, trade, and climate change in Africa

Our findings are in line with recent policy discussions around the implications of increased carbon dioxide emissions on climate change in Africa. One of the major sources of the emission of greenhouse gases in Africa is shipping, thereby contributing significantly to climate change. According to a report by UNCTAD (2020), the carbon dioxide emissions from shipping in Africa increased by 28% between 2012 and 2018. This increase is mainly attributed to the growth of the shipping industry in Africa, which has led to the use of more fossil fuels. The report also highlights that majority of African countries lack the necessary infrastructure and resources to monitor and regulate the emissions from ships, which further exacerbates the problem.

Another environmental issue linked to the shipping of goods in Africa is the discharge of ballast water from ships. Ballast water is taken on board ships to maintain stability and balance during voyages, but it often contains harmful aquatic organisms that can be released into new ecosystems when the water is discharged. This can have devastating effects on local marine life and ecosystems, as invasive species can disrupt the natural balance and cause significant economic and environmental damage. In response to this problem, the International Maritime Organization (IMO) has developed the Ballast Water Management Convention, which requires ships to manage their ballast water to prevent the spread of invasive species. However, the implementation of the convention has been slow in Africa due to limited resources and capacity in many countries, hence the continuous increase in carbon dioxide emissions from the shipping industry, thereby resulting in climate change, as we point out in our empirical findings.

Notwithstanding the increasing emissions of climate-endangering gases from Africa, policies are being implemented to reduce the emissions. Most of the African countries that have signed international treaties have adopted policies aimed at reducing carbon dioxide emissions. For example, the Paris Agreement, signed in 2015, aims to limit the increase in global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the increase to 1.5 °C (United Nations 2015). Most African countries have submitted their nationally determined contributions (NDCs) to the Paris Agreement, which outline their commitments to reducing greenhouse gas (GHG) emissions and adapting to the impacts of climate change. In addition, some African countries are implementing policies that promote renewable energy usage, and energy efficiency, which can reduce the emissions associated with shipping while also promoting sustainable development.

Furthermore, African countries have also taken steps to implement the United Nations Sustainable Development Goals (SDGs), which aim to end poverty, protect the planet, and ensure prosperity for all. Some of the SDGs, such as Goal 13 (Climate Action), Goal 14 (Life Below Water), and Goal 15 (Life on Land) (United Nations 2015) are closely linked to the impact of trade on climate change. As a result, African countries adopting policies that are in line with these SDGs, such as promoting sustainable land use and conservation, protecting marine ecosystems, and reducing GHG emissions. These policies demonstrate a commitment to sustainable development and to addressing the significant impact of trade in general and shipping in particular on climate change, as highlighted in our findings.

A more recent trade policy significant in reducing the impact of trade on climate is the African Continental Free Trade Area (AfCFTA), which aims to increase intra-African trade and promote economic growth while reducing the carbon footprint associated with international trade (African Union 2018; International Center for Trade and Sustainable Development 2019; World Trade Organization 2021). The AfCFTA is expected to promote the use of sustainable transport and reduce the emissions associated with long-distance transportation of goods. In addition, the AfCFTA is expected to promote the use of renewable energy and increase access to clean energy technologies, which can help to reduce the carbon intensity of African economies. Taken together, our findings could further develop interest in discussing ways of reducing gaseous emissions that contribute significantly to climate change in Africa.

Conclusion and policy suggestions

The impact of trade and shipping on climate change has received much attention from policymakers in recent times. While studies on the direct effects of trade and shipping have been examined, what is unknown empirically is the role of trade in the relationship between shipping and climate change. In this paper, we employ a panel dataset covering the period 2006 to 2016 for a total of 31 African countries and the system-generalized method of moments approach to examine the role of trade in the relationship between shipping and climate change in the context of African countries. After controlling for income, population density, government spending, foreign direct investment, and quality of institutions, we document evidence of a significant impact of trade and shipping on climate change in Africa. Specifically, we find that trade and shipping significantly increase climate change directly in African countries in both the short and long-run periods. More importantly (the focus of this study), the results suggest that trade increases the impact that shipping has on climate change in African countries. Also, the marginal effects results show that as we move upward the percentile scale, the impact of shipping on climate change increases as trade increases in the short run and long run periods.

Although increasing trade via shipping to improve the welfare of the citizenry is important, based on the findings, policies that are aimed at reducing carbon dioxide emissions or mitigating the impact of climate change effects would go a long way in promoting sustainable economic development in Africa. Despite these findings, this study is not without limitations: we envisage a mutual causality between container shipping connectivity and trade. It is therefore vital that future research focuses on the causality between container shipping connectivity and trade in Africa. Doing so may be able to establish the possibility of the existence of a bidirectional relationship between shipping and international trade in Africa.

Appendix

See the Table 6, 7 and 8.

Table 6 Correlation matrix results

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) CC	1.000							
(2) SP	− 0.027	1.000						
(3) TRD	0.011	− 0.057	1.000					
(4) PD	− 0.061	0.087	− 0.005	1.000				
(5) INC	0.935	− 0.015	0.049	− 0.123	1.000			
(6) GSP	0.466	0.057	− 0.026	− 0.276	0.415	1.000		
(7) FDI	− 0.105	− 0.020	− 0.001	− 0.080	− 0.117	0.187	1.000	
(8) IQI	0.026	− 0.082	0.019	0.057	0.031	0.064	0.084	1.000

Source: Authors

Table 7 Results of variance inflation factor

Variables	VIF	1/VIF
SP	1.03	0.971
TRD	1.01	0.992
PD	1.11	0.905
INC	1.28	0.783
GSP	1.39	0.718
FDI	1.10	0.911
IQI	1.03	0.925
Mean VIF	1.13	

Source: Authors

Table 8 List of countries

Algeria	Gabon	Mozambique
Angola	Gambia	Morocco
Benin	Ghana	Namibia
Cameroon	Guinea	Nigeria
Congo Rep	Guinea. Bissau	Senegal
Comoros	Kenya	Seychelles
Congo. Demo. Republic	Liberia	Sierra-Leone
Cote Devoir	Madagascar	South Africa
Equatorial Guinea	Mauritania	Tunisia
Egypt	Mauritius	Togo
		Tanzania

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Declarations

Competing interests
The authors declare that they have no competing interest.

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