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Trade and Climate Change: Impacts and Interactions

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A B S T R A C T

The relationship between international trade, the environment, and climate change is examined in further detail in this study. Kenya, the biggest exporter in East Africa, is vulnerable to climate change. The current analysis, which takes into account Kenya's economy for the years 1993–2023, is based on the straightforward ordinary least square method to determine the significant relationship between trade and climate change. Temperatures are used in the study as climate change indicators. To provide a thorough examination of the dynamics of climate change, the research takes into account several aspects, including trade indicators, carbon emissions, industrialization, and urbanization. It was found that export positively and significantly affects climate change in Kenya. The positive impact of imports on climate change is negligible. The study finds evidence of a bidirectional causal relationship between trade and climate change using multivariate Granger causality tests. According to the result, sustainable production methods should be promoted, renewable energy should be encouraged, and fair-trade policies that put environmental responsibility first should be implemented.

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INTRODUCTION

Trade and climate change have a complicated, interconnected relationship. International trade can contribute to climate change by increasing emissions from transportation and production, whereas climate change can disrupt trade by altering production conditions and supply chains (Alejandra et al., 2023). However, trade may also be an important tool for reducing and adapting to climate change, providing chances for innovation and efficiency in environmentally friendly products and solutions.

Economists evaluate the environmental impact of trade liberalization using three criteria: scale, composition, and technique. The "scale" impact is the increase in greenhouse gas emissions caused by increased economic activity as a result of freer trade. The "composition" impact refers to changes in a country's production mix towards commodities with a comparative advantage, which influences emissions depending on the sectors involved. Finally, the "technique" impact implies that trade can lead to advances in energy efficiency, lowering greenhouse gas emissions during production (WTO, 2013). The study uses the scale effect to examine the effects of international trade on climate change.

Climate change will affect some of these aspects, altering trade and specialization patterns via various methods. Some climate consequences, such as increased frequency of extreme events, severe temperatures, or rising sea levels, will have a direct impact on trade since they will disrupt transportation and distribution chains (Dellink et al., 2017). Changes in an economy's factors of production (such as land, labour, and capital) will also have an impact on production structure and trade specialization. However, climate change is predicted to have an indirect impact on trade because all regions and sectors are linked via production inputs and trade in produced goods and services (Willenbockel, 2012).

According to Climate Prediction Centre data, average maximum temperatures in Kenya are warming, rising from 29.0°C in the late 1970s to 30.5°C by the early 2020s, a 1.5°C increase linked to global climate change (KDM, 2024). Figure 1 depicts the average earth temperature in Kenya.

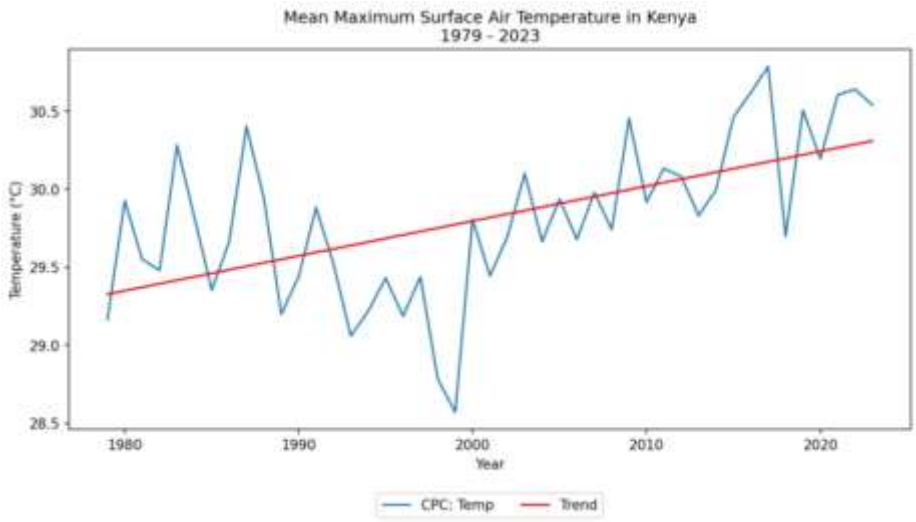

Figure 1. Average mean surface temperature in Kenya 1979-2022

Trade is thought to have a considerable impact on climate change. It is important to consider not only the direct emissions from carrying commodities, but also the larger impact of commerce on production, consumption, and resource usage. Essentially, international trade, both export and import, exacerbates both the causes and effects of climate change (WTO, 2013). Kenya's commercial landscape reflects a pattern of rising import values and a developing, if unpredictable, export industry. In 2023, overall imports were Ksh 2.6 trillion, while exports were Ksh 1 trillion. Between 2019 and 2023, imports increased by 30.9% and exports by 39.1%. However, in recent months, both export and import values have declined, with trade volume expected to fall in 2024 (KNBS, 2024).

Kenya has launched programs such as the National Climate Change Action Plan and is committed to lowering emissions by the Paris Agreement. However, there is a scarcity of empirical studies assessing the export and import sectors' contributions to climate change in the nation. This study aims to close that gap by using time series data from 1993 to 2023 to assess the impact of exports and imports on climate change in Kenya.

LITERATURE REVIEW

The assumption that manmade greenhouse gas emissions are the principal cause of climate change is being challenged by evidence that other human activities have a greater impact (Sidiropoulos, 2023). The Human Climate Forcings theorem (Omotoso & Omotayo, 2024) shows that land-use changes, deforestation, trade, agriculture, urbanization, and industrial practices all have a major impact on land and sea surface temperatures. Logging, agriculture, trade, building, and tourism all have an impact on climate because they destroy ecosystems and change water dynamics. For example, deforestation reduces CO2 sequestration, whereas urban expansion might cause more runoff and higher temperatures.

The Scale Effect theory, developed by Grossman and Krueger (1993) and Copeland and Taylor (1994), proposes that more international trade leads to a larger global scale of production, which can result in higher environmental degradation and pollution. This is because more goods and services are manufactured to fulfil rising demand, potentially increasing resource consumption, pollution, and waste. The composition impact idea in international commerce emphasizes how trade can change the mix of sectors in various countries, potentially resulting in a concentration of "dirtier" businesses in certain areas and "cleaner" industries in others. This transition can have an impact on overall pollution levels when the relative prominence of polluting businesses in a country's economy changes (Yolanda et al., 2023). The Ricardian model of international commerce, a core theory in classical economics, explains trade in terms of comparative advantage, which occurs when countries specialize in providing commodities and services with lower opportunity costs. This specialization and trade result in more effective resource allocation and, theoretically, lesser environmental impact by concentrating production in regions of comparative advantage (Gupta, 2015; Deardorff, 2007).

According to the empirical literature assessment, climate change damages may have an impact on international commerce, while international trade can reduce climate change costs (Willenbockel, 2012; Dellink et al., 2017). Willenbockel (2012) looks into the impact of extreme weather events on food prices and international trade. He demonstrates how regional productivity shocks can have quite different effects on food prices, export prices, and export volumes. The link between commerce and climate change is intricate and complicated. Trade can exacerbate climate change by increasing emissions from production and transportation, while also providing chances for mitigation and adaptation by promoting the exchange of commodities and technologies and incentivizing ecologically benign practices. Emissions transfers, in which a country's environmental impact is transferred to another country through trade, are also an important factor. This study seeks to shed light on how international trade indicators such as exports and imports contribute to climate change damage by aggravating global warming. As a result, the relationship between commerce and environmental impacts is complex and deserves careful consideration. However, enacting suitable trade and environmental policies can provide effective economic incentives for both long-term prosperity and climate change mitigation.

METHODOLOGY

The investigation was done in Kenya from 1993 to 2023, yielding a total of 31 observations. Data on climate change, characterized by rising temperatures, were collected from the World Bank's Climate Change Knowledge Portal (CCKP), which provides global information on climate change and development. Furthermore, data on explanatory factors, such as trade indicators like exports and imports, as well as control variables like carbon emissions, industrialization, and urbanization, were obtained from the World Bank's World Development Indicators (WDI) database. Table 1 describes the factors used in this investigation.

Table 1: Variables used in the econometric analysis

Variable	Description	Source	Prior sign
Exports (EXP)	Exports of goods and services (% of GDP)	WDI	Positive (Willenbockel, 2012)
Imports (IMP)	Imports of goods and services (% of GDP)	WDI	Positive (WTO, 2013)
Carbon emissions (CO2)	Per capita CO2 (Metric tons)	WDI	Positive (Kipchirchir et al., 2024)
Industrialization (IND)	Industry, value added (% of GDP)	WDI	Positive (Tanchev et al., 2024)
Urbanization (URB)	Urban population (% total population)	WDI	Positive (Tanchev et al. 2024)
Climate change (TEMP)	Average temperature (°C)	CCKP	Dependent variable (Chamma, 2024)

Empirical analysis uses the following econometric model

$$TEMP_t = \delta_0 + \delta_1 EXP_t + \delta_2 IMP_t + \delta_3 CO2_t + \delta_4 IND_t + \delta_5 URB_t + \varepsilon_t \quad (1)$$

where δ represents the elasticities of the variables in the regression model. t represents the time dimension and ε is the error term.

This study used descriptive, correlation, and regression analysis of time series data to investigate the impact of trade indicators on climate change in Kenya. To confirm the accuracy of the predicted results, the study first used the Augmented Dickey-Fuller (ADF) unit root test to assess each variable's stationarity. Following that, a cointegration test using the Johansen technique was used to evaluate the long-term associations between the time-related variables. To estimate the regression outcomes, the analysis used the least squares estimation approach within a multivariate linear regression model. To study the causal links between the variables, Granger causality tests were used. Finally, a battery of post-diagnostic tests, including the Jarque-Bera normalcy test, Breusch-Godfrey serial correlation tests, and the Breusch-Pagan heteroscedasticity test were used to confirm the model and results.

RESEARCH RESULT AND DISCUSSION

Descriptive analysis was pesrformed to establish the characteristics and patterns of study variables. Table 2 shows the descriptive results.

Table 2. Descriptive statistics results

Variable	TEMP	EXP	IMP	CO2	IND	URB
Mean	24.9961	21.9976	29.7348	0.2901	16.9845	21.9075
Median	25.0200	21.9189	30.2747	0.2644	17.0035	21.6750
Maximum	25.4900	38.9036	39.1540	0.4105	19.6629	27.9950
Minimum	24.5700	9.6418	17.5959	0.2024	13.5565	16.7480
Std. Dev.	0.2431	6.8461	4.9817	0.0606	1.7348	3.3870
Observations	31	31	31	31	31	31

According to the secondary data analysis, many of the economic indicators in Table 2 vary significantly. The period spans from 1993 to 2023, with a total of 31 observations. Kenya's temperature stability is minimal, as indicated by the average temperature of 24.99 and the moderate standard deviation of 0.24. Trade output varies across the sample, with a mean value of 21.99% of GDP for exports and 29.73% of GDP for imports, and large standard deviations of 6.84 and 4.98. A pairwise correlation analysis was used to determine the relationship between the target study variables. Table 3 shows a matrix of data correlations for Kenya.

Table 3: Correlation matrix results

Variables	TEMP	EXP	IMP	CO2	IND	URB
TEMP	1					
EXP	0.5835***	1				
IMP	-0.3893**	0.7724***	1			
C02	0.5057***	-0.8147***	-0.6971***	1		
IND	0.4551**	-0.5605***	-0.1929	0.5439**	1	
URB	0.6653***	-0.8347***	-0.5963***	0.8455***	0.6581***	1

It is demonstrated that export trade has a significant positive relationship with temperature, meaning that export trade levels have a significant impact on Kenyan temperatures. However, imports have a negative relationship with temperature levels, implying that higher imports are associated with lower temperatures. Carbon emissions, industrialization, and urbanization all have a positive relationship with temperature levels, meaning that increased carbon emissions, urbanization, and industrialization are linked to rising temperatures and subsequent climate change. The study used the Augmented Dickey-Fuller (ADF) test equation to determine the stationarity of the dependent and independent variables. Table 4 displays the stationarity regression results.

Table 4: Unit root test result

Variables	ADF at Level		ADF at First difference		Decision
	t-Statistics	P-value	t-Statistics	p-value	
TEMP	-5.6046	0.0002	-	-	I(0)
EXP	-0.7818	0.8098	-4.8114	0.0006	I(1)
IMP	-1.4096	0.5643	-5.1841	0.0002	I(1)
CO2	-0.3984	0.8972	-4.4000	0.0017	I(1)
IND	-5.2920	0.0002	-	-	I(0)
URB	0.5517	0.9856	-4.1690	0.0142	I(1)
Notes: Null Hypothesis: variable has a unit root					

The findings of the Augmented Dickey-Fuller (ADF) unit root test show heterogeneous integration among the variables under investigation. The analysis finds that climate change and industrialization exhibit stationarity at the level, while exports, imports, carbon emissions, and urbanization exhibit stationarity at the first difference. These findings reflect a considerable differential in the variables' integration qualities, emphasizing the importance of careful consideration in future econometric modelling and analysis.

To estimate long-run associations using the Johansen cointegration approach, all of the model's time series variables must be integrated into order one. However, the findings of the Augmented Dickey-Fuller (ADF) test show that the variables have mixed integration qualities. This observation implies that the assumption of cointegration may not be relevant in this situation. The multivariate regression model was estimated using the ordinary least squares (OLS) regression technique. Table 5 reveals the regression results.

Table 5: Estimated OLS Model

Variable	Coefficient	Standard error	t- Statistics	p – Value
EXP	0.2787	0.0963	2.8923***	0.0076
IMP	0.0360	0.1023	0.3519	0.7277
CO2	0.0611	0.0224	2.7200**	0.0119
IND	0.3600	0.1469	2.4503**	0.0213
URB	0.3826	0.1433	2.6700**	0.0129
CONS	0.6246	0.1187	5.2612***	0.0000
Goodness of Fit Test	Adjusted R-squared		0.6799	

Durbin-Watson statistics	1.8150	
Breusch-Pagan Godfrey Test	χ^2 (5) = 1.2472	Prob> χ2 = 0.3173
Breusch-Pagan LM Test	χ2 (5) = 4.4995	Prob> χ2 = 0.0061
Jarque-Bera test	1.1369	Prob=0.5176

According to the study, increasing exports would result in a 27% increase in Kenya's mean temperature. A rise in exports of goods and services raises the average global temperature, resulting in climate change. The prevalent assumption is that trade liberalization will boost economic activity and thus energy consumption. Everything else being equal, the increased scale of economic activity and energy consumption will result in higher amounts of greenhouse gas emissions. Furthermore, exports have a considerable impact on climate change, owing to greenhouse gas (GHG) emissions connected with the manufacture and transportation of export goods and services. These emissions, which account for a sizable fraction of global GHG emissions, have the potential to exacerbate climate change and its repercussions. Finding evidence for the Scale effect theory, which states that more commerce leads to a larger scale of production internationally, potentially resulting in more pollution and environmental damage (Grossman & Krueger, 1993; Copeland & Taylor, 1994). The findings are consistent with the empirical research by Willenbockel (2012) and Dellink et al. (2017). Willenbockel (2012) looks into the impact of extreme weather events on food prices and international trade. He demonstrates how regional productivity shocks can have quite different effects on food prices, export prices, and export volumes. Trade, on the other hand, can help nations adjust to rising average temperatures and more severe weather events by offering consumers low-emission products and services (Dell et al., 2012).

Imports, albeit insignificant, have a positive impact on climate change. The import sector has little impact on climate change in Kenya. While commerce may contribute to climate change by increasing energy consumption and emissions, it also has the potential to assist in alleviating climate change by providing lower-emission goods and services and facilitating the development of climate-friendly technologies. Climate change can also hurt trade, disrupting supply networks, infrastructure, and agricultural production.

Carbon emissions have a big, positive impact on climate change. Carbon dioxide is the major greenhouse gas that causes global warming by trapping the sun's heat, resulting in rising global temperatures and shifting weather patterns. This issue is linked to human activity, particularly the combustion of fossil fuels such as coal, oil, and gas, which emit huge amounts of carbon dioxide into the atmosphere. Industrialization has a major and favourable impact on climate change, owing to the increased emission of greenhouse gases, mainly carbon dioxide. Since the Industrial Revolution, human activities such as the combustion of fossil fuels and manufacturing processes have released huge amounts of greenhouse gases into the atmosphere, causing global temperatures to rise and climatic patterns to shift. Urbanization has a large and positive impact on climate change, both by contributing to it and increasing cities' vulnerability to its effects.

Urban areas are large emitters of greenhouse gases, especially from transport and structures (Kinuthia & Mose, 2024). Climate change exacerbates urban issues such as heat islands, extreme weather events, and infrastructure strain.
The model's adjusted R-squared value is 0.68, indicating that the independent variables included in the model can account for approximately 68% of the variability in the dependent variable. Furthermore, serial correlation is not a major concern in the dataset, according to the Durbin-Watson statistic, which was calculated at 1.81. Furthermore, the results of the Breusch-Pagan heteroscedasticity test demonstrate that heteroscedasticity is not a significant issue in the analysis.

The study applied Granger causality analysis to establish the association between study variables. Table 6 presents the causality result.

Table 6: Pairwise Granger Causality Tests

Direction	F-Stat.	Prob.	Decision
TEMP → EXP	7.0815	0.0673	Bidirectional
EXP → TEMP	10.8388	0.0376	
TEMP → IMP	1.6575	0.3709	No causality
IMP → TEMP	4.2086	0.1320	
Notes: lags 1; observations 30, Null hypothesis: does not granger cause			

The study revealed a bidirectional causal relationship between trade indicators, specifically exports, and climate change. This shows that commerce in exports not only adds to global warming emissions but is also influenced by climate change as comparative advantages alter (Grossman & Krueger, 1993; Copeland & Taylor, 1994). Interestingly, imports have no association with climate change. While international trade adds to global warming, it has the potential to improve overall welfare in a variety of ways. It encourages economic growth, lowers prices, and expands consumer choice and product diversity. Furthermore, international commerce can help tackle climate change by enabling the flow of environmentally friendly goods, services, and innovations (Alejandra et al., 2023). The feedback connection results are consistent with the findings of Dellin et al. (2017) and Willenbockel (2012).

CONCLUSIONS AND RECOMMENDATIONS

Trade flows are acknowledged in the academic literature as important factors in a country's economic activity and energy use. An increase in economic activity or output, combined with increased energy consumption, frequently results in higher temperatures and fewer precipitations, aggravating climate change. On the contrary, by providing consumers with low-emission goods and services, trade can help countries adapt to rising temperatures and more severe weather events. The relationship between commerce and environmental results

is complex and deserves careful consideration. This study looks into the drivers of climate change in Kenya, with an emphasis on the combined effects of the export and import sectors.

The purpose of this research is to examine the influence of free trade on climate change, with an emphasis on the relationship between trade indicators—specifically, exports and imports of commodities and services—and climate change, which is characterized by rising temperatures. The study uses the least squares estimate technique within a multivariate linear regression framework to investigate time series data from Kenya from 1993 to 2023. The findings show that exports have a considerable beneficial impact on climate change, whereas imports have little effect. The findings suggest that commerce, as defined by exports and imports, hurts climate change, but with variable degrees of severity. The studies also show that carbon emissions, industrialization, and urbanization are major causes of climate change in Kenya. Furthermore, the coefficient reveals a strong causal relationship between exports and climate change, as well as vice versa. The causality results show that climate change damages may have an impact on international trade, whilst international trade can reduce climate change costs. The study emphasizes the necessity of incorporating climate change considerations into the export and import sectors, as well as supporting carbon development routes.

While export activities can contribute to climate change in a variety of ways, including the carbon footprint of producing and shipping goods, there are measures available to offset these consequences. To reduce the climatic impact of exports, policymakers should focus on lowering the carbon footprint of traded goods and services through a variety of means, including carbon price, environmental standards, and international cooperation. This includes incentivizing low-carbon production, lowering trade barriers for sustainable technologies, and promoting environmentally responsible consumption and production habits. Reducing border wait times and streamlining inefficient customs procedures can help cut trade-related emissions, particularly as trade volumes increase. Kenya may successfully reduce the climate impact of its exports by enacting these policies, as well as promoting sustainable and fair global trade practices.

To reduce the climatic impact of imports, a holistic approach is advocated, which includes trade facilitation, tariff modifications, and promotion of sustainable consumption habits. Trade facilitation methods can improve import operations and reduce energy usage during transportation. Carbon import tariffs and Border Tax Adjustments (BTAs) can encourage greener production while reducing imports of carbon-intensive products. Furthermore, raising consumer knowledge and education about sustainable purchasing patterns can lead to more environmentally friendly imports. To minimize trade's climate impacts through feedback mechanisms, policy proposals should prioritize green government procurement (GGP), renewable energy and environmental goods promotion and trade standard harmonization. Additionally, decreasing damaging fossil fuel subsidies and enhancing resource efficiency are critical initiatives.

ADVANCED RESEARCH

This study has certain limitations; therefore, future research is recommended with broader scope and approach to obtain more optimal results.

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