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CLIMATE CHANGE ADAPTATION AND AGRICULTURAL TRADE FLOWS IN AFRICA: EMPIRICAL EVIDENCE FROM NIGERIA

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Abstract

This paper examines how intra-African agricultural trade flows can serve as an adaptation mechanism to the impact of climate change in Africa. Specifically, it estimates the impact of climate and environmental variables on trade flows between Nigeria and 14 selected countries in Africa using the reduced form of gravity model. Estimation is done with the Fixed Effect and Hausman-Taylor regression techniques using panel data for the period 2006 to 2018. The result from both fixed effect and Hausman-Taylor model shows that the GDPT parameter estimates are positive and significant in both regressions indicating that the higher the GDP of both the exporting and importing countries, the higher the value of trade which is in line with the standard gravity model of international trade. Again, the result from the fixed effect and Hausman-Taylor model shows that rainfall and temperature play a significant role in promoting trade. Also, the similarity or differences in the distribution of these climatic variables significantly affect trade in both models. These results underscore the significance of taking into account climate change adaptation friendly policies in the AfCFTA treaty.

Keywords: Adaptation, Agricultural Trade Flows, Climate Change

JEL Classification: Q17; Q34

1. Introduction

Climate change is expected to affect the global food system (Vermeulen, Campbell, & Ingram, 2012) and its implications for food and nutrition security is well-documented in the extant empirical literature (Myers et al., 2017). With the projected increase in global average temperature, more regions may experience temperature-related yield stagnation and even declines, affecting overall food production and the other components of food systems (Ray et al., 2019; Vermeulen et al., 2012). Recently, extreme weather event due to climate change have had severe impact on global agricultural yields (Vogel et al., 2019). Extreme temperature and rainfall in particular are considered the major threats to crop production, causing devastating floods and droughts which has far reaching implication on agricultural production in both developed and developing countries (Wilhite, 2000). By altering spatiotemporal crop productivity (Zhang, Cai, Beach, & McCarl, 2014), climate change-induced weather extremes are expected to impact on global food prices in the future (Easterling et al., 2006). Differences in productivity is not restricted to cross country but can be found within a single country with multiple climatic zones (Beach et al., 2010; Reilly et al., 2003). Consequently, Climate change is projected to lead to significant changes in the geographical distribution of agricultural production potential, with increases in mid to high latitudes and a decrease in low latitudes (Huang, von Lampe, & van Tongeren, 2011). This shift in production potentials is expected to lead to higher trade flows of mid to high latitude agricultural products such as cereals and livestock compared to low latitudes products (Huang et al., 2011). Fischer, Velthuizen, Shah, & Nachtergaele (2002) report that by 2080, cereal imports by developing countries would rise by 10–40%.

For a vulnerable region like Africa, appropriate policy response to adapt to the effect of climate change on continental-wide trade flows generally and on agricultural trade flows in particular call for empirical research. As such, the objective of this paper is to examine how intra-African agricultural trade flows can serve as an adaptation mechanism to the impact of climate change in Africa. Specifically, it estimates the impact of climate and environmental variables on trade flows between Nigeria and 14 selected countries in Africa using the reduced form of gravity model. To achieve the objective, the paper is structured into five sections. Following the introduction is section two, which is concern with the empirical review of literature. Section three looks at the methodology. In section four, we present the empirical result and section five concludes the paper.

2.0 Conceptual Framework and Literature Review

Over time, climate change poses a different challenge from that of managing extreme weather events. On a decadal scale for example, it is expected that the fundamental patterns of comparative production advantage will change. Agriculture is likely to expand in regions which are relatively more productive and have lower production costs. This will be driven by differences in crop productivity growth rates, changing variability in environmental factors (precipitation, temperature and ground water for irrigation), as well as shifting availability of economic endowments (labor force and capital for new investments) (Baldos & Hertel, 2015).

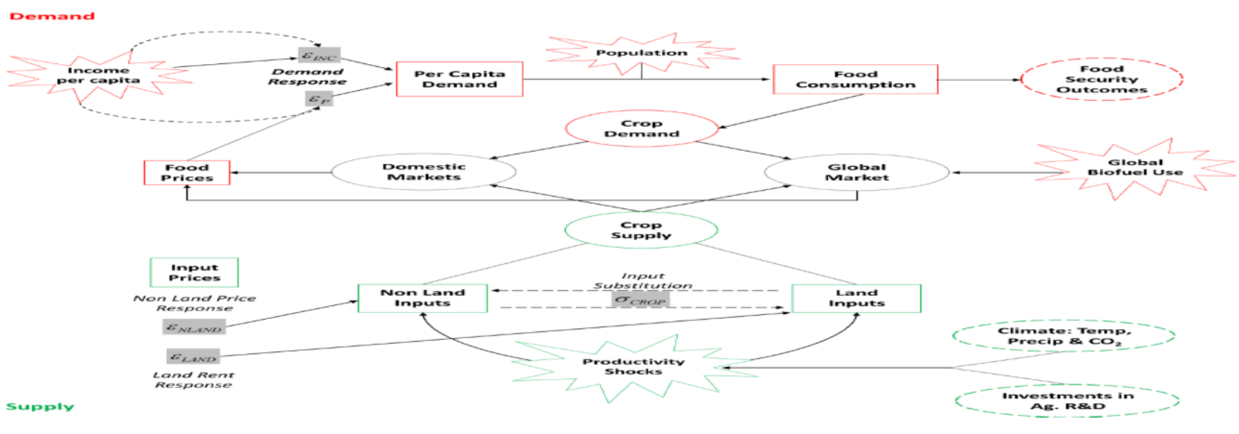

Figure 1: Simplified International Model of agricultural Prices, Land use and the Environment
Source: Baldos & Hertel (2015)

Baldos & Hertel (2015) argued that without global restrictions, trade patterns will respond to the evolving comparative advantage as illustrated with the Simplified International Model of agricultural Prices, Land use and the Environment (SIMPLE). As shown above, the model of global agricultural production, consumption and trade explores the long run evolution of regional demand and supply for food, and the potential for achieving improved long run food security in the context of a more tightly integrated global trading system (Baldos & Hertel, 2015; Zimmermann, Benda, Webber, and Jafari, 2018).

The conceptual framework above guides the identification and review of related literature which shows that Climate change impacts on global agriculture and its implication for international trade have been examined in several previous studies. For example, John Reilly & Hohmann (1993), Parry, Rosenzweig, Iglesias, Livermore, & Fischer (2004), Nelson et al. (2009), Nelson et al. (2010), Chen & Dall'Erba (2018) and Dissanayake, Mahadevan, & Asafu-adjaye (2019) conducted their assessments under a variety of different climate and socioeconomic scenarios. Other studies that directly investigated the interaction between climate policies and trade include Pothen & Hübler (2018), Dallmann (2018) and Vrontisi, Charalampidis, & Paroussos (2020). Focusing specifically on adaptation policy, Ouraich, Dudu, Tyner, & Cakmak (2019) used GTAP model to analyze the extent to which agricultural trade liberalization can be an adaptation strategy in the face of climate change within the context of trade relations between Morocco and Turkey. Similarly, Bouet et al. (2018) develop a quantitative general equilibrium trade model where the representation of acreage and land use choices were inspired from modern Ricardian trade models but also consistent with theoretical and empirical literature on land use choices to quantify the role of international trade in attenuating the effects of climate change. The paper by Tembata & Takeuchi (2018) analyzed the effect of climate related disasters on international trade in Southeast Asia using panel data econometric methods.

In a recent review of the extant empirical literature on the effects of natural disasters and weather variations on international trade and financial flows, Osberghaus (2019) reports that although the effect of natural disasters on trade flows are more ambiguous, exports are affected negatively by the occurrence and severity of disasters in the exporting country. Imports, on the hand, may increase, decrease or remain unaffected by natural disasters. With respect heterogeneous effects, Osberghaus (2019) found that small, poor and hot countries with low institutional quality and limited political freedom suffer more from the effects of weather shocks.

Important limitations in the aforementioned studies is that detailed cross-country study on the impact of weather shock on African agricultural trade, especially in the context of African Continental Free Trade Area (AfCTA) which is aimed at increasing intra-African trade flows have not been addressed. Also, as identified by Osberghaus (2019), the potential of trade as an adaptive mechanism to mitigate the negative effects of climate change induced weather shocks have not been taken into account. This paper contributes to the discussion on how agricultural market institutions in general and regional trade in particular can be used to reduce the negative effects of climate change and extreme weather events on food and nutrition security in Africa specifically and the world at large.

3.0 Data Sources and Structure

To address this important gap in the extant empirical literature, this paper examines how climate change affects intra-African trade flows using the reduced form gravity model that captures the impact of climate change on Nigeria's agricultural exports. Estimation is done using rainfall, temperature as well as indexes of import and export of selected agricultural crops and countries in the study region. The climate data is sourced from varied sources while trade data is sourced from Food and Agricultural Organization (FAO) and World Trade Organization (WTO) website. The data set employed in the paper covers 14 African countries which include Algeria, Angola, Benin, Cameroon, Egypt, Ghana, Guinea, Kenya, Morocco, Namibia, South Africa, Togo, Congo and Chad over the period of 2006-2018. All variables are in constant dollar prices with 2010 as the base year. The variable measurement is explained below. The collection of exports data is based on Nigeria's trade flow with her trading partners, the data is sourced from World Integrated Trade Solutions (WITS) database. The GDP and CO2 emission data for Nigeria and her African trading partner is obtained from World Bank IFS statistics, while data on temperature and rainfall are obtained from https://climateknowledgeportal.worldbank.org. Data on the geographical distance between Nigeria and her trading partners is obtained from the French Institute for Research on the International Economy (CEPII) database. Similarly, BORDER is a dummy variable that takes the value of 1 if Nigeria and its trading partner share the same boundary and 0 otherwise. In the present study, Benin and Cameroon share boundary with Nigeria while others do not. Also, the variable COL indicates countries that share similar colonial history with Nigeria. The countries identified in this study are Ghana and Kenya which take the value of 1 and 0 for other countries who do not. We introduce the KOF (Swiss Economic Institute) globalization as a control variable, since it provides information about the economic structures of countries. The index which measures the economic, social and political dimensions of globalization is compiled by Gygli, Haelg, Potrafke, & Sturm (2019). Note that the commonly used panel data structure set-up of gravity equation is unbalanced, as no country exports to itself. Because of this, there are 153 data points for the estimation.

3.1 Methodology and Model Specification

Gravity model is mostly used for ex-post analyses of trade flows. As a workhorse econometric model, it is generally used for estimating the impact of series of policy issues and has its theoretical foundation in the Newton's law of gravitation. Newton's law of universal gravitation states that 'any particle of matter in the universe attracts any other with a force varying directly as the product of the masses and inversely as the square of the distance between them'[i]. First proposed by Tinbergen (1962) to explain bilateral international trade, gravity model gained prominence among scholars for its analogy with Newton's law of gravitation. The gravity model is based on the idea that overall trade volumes between two nations depend on the size of the two nations and how far apart the two countries are (the distance). In other words, the standard formulation of gravity model describes bilateral trade flows in line with Isaac Newton's law of gravity, by stating that the attraction of two countries' masses (measured by GDP and/or population), is reduced by the distance (approximated by transport costs) and other factors (Bekele & Mersha, 2019). The standard specifications of Newton's law of gravitation and the gravity model are as follows:

Newton's law of universal gravitation

$$F_{ij} = \frac{GM_i M_j}{D_{ij}^2} \qquad 1$$

F= attraction; M= mass; D= distance; G= gravitational constant

Gravity model

$$X_{ij} = \frac{KY_i^{\alpha} Y_j^{\beta}}{T_{ij}^{\sigma}} \qquad 2$$

X_{ij}= export of i to j; or total trade $(X_{ij} + X_{ji})$

Y= economic size (GDP, Population)

T= trade cost

Standard proxies for trade cost in the literature are distance, adjacency, common language, colonial links, common currency, island (landlocked), institutions, infrastructure, migration flows, tariffs etc. Surprisingly, climatic variables (differences in climate cause by variation in rainfall and temperature across countries) are missing. Although, most studies found these explanatory variables to be significant (ref), the criticism often leveled against this approach is that, researchers have extended the gravity model beyond its confines in an ad hoc manner (Ghosh & Yamarik, 2004). As evident in equation 1 & 2, the size of GDP and geographic distance constitute the building blocks of gravity equation and can be justified by the Heckscher–Ohlin (H-O) model and new trade theories based on imperfect competition (ref).

In this study, we use the gravity equation in its original form which is specified as

$$X_{ij} = \frac{A(GDP_i GDP_j)^{\pi_1}}{D_{ij}^{\pi_2}} \qquad 3$$

Where Π's are elasticities, X_{ij} is the value of export from country i to country j, GDP_i and GDP_j are GDP of countries i and j respectively, D_{ij} captures transportation cost and a measure of the distance between the two countries. In its original form, A represents a constant as used in some empirical studies that used gravity model (see for example). However, due to heterogeneity across countries, individual country effect are allowed to vary in this study and is specified as a function of its capabilities i to its trading partner j (Wang, Wei, & Liu, 2010). Therefore, A_{ij} measures the interaction between domestic and trading partners' variables (that is, climate, environmental and globalization). Thus,

$$A_{ij} = e^{\pi i}(TEMP_i TEMP_j)^{\pi_3}(RAIN_i RAIN_j)^{\pi_4}(CO2EM_i CO2EM_j)^{\pi_5}(OPP_i OPP_j)^{\pi_6} \qquad 4$$

Where $TEMP_{i(j)}$, $RAIN_{i(j)}$, $OPP_{i(j)}$ and $CO2EM_{i(j)}$ are country i(j)'s domestic temperature, rainfall, openness and CO^2 emission variables respectively. Substituting equation 4 into 3 and taking natural log, we have

$$InX_{ij} = \pi_i + \pi_1 InGDP_i GDP_j - \pi_2 InD_{ij} + \pi_3 InTEMP_i TEMP_j + \pi_4 InRAIN_i RAIN_j + \pi_5 InCO2EM_i CO2EM_j + \pi_6 InOPP_i OPP_j \qquad 5$$

The prefix? In indicates natural log. The second term in equation 5 can be arrange as

$$InGDP_i GDP_j = -In2 + 2InGDPT_{ij} + InSIMGDP_{ij} \qquad 6$$

Where $GDPT_{ij} = GDP_i + GDP_j$ and

$$SIMGDP_{ij} = 1 - \frac{GDP_i^2}{(GDP_i + GDP_j)^2} - \frac{GDP_j^2}{(GDP_i + GDP_j)^2}$$

Equation 6 shows that volume of export depends on the market size (GDPT) which is equivalent to the average GDP. SIMGDP measures the similarity in the level of GDP between the trading partners; it captures the relative size of the two countries in terms of the GDP. This variable may vary within the range of 0 (absolute divergence in size) and 0.5 (equal country size). The larger this measure is, the more similar the two countries in terms of the size of their GDP, the higher the share of intra-industry trade.

Similarly, the third, fourth, fifth and the sixth term can be specified as follows

$$InTEMP_i TEMP_j = -In2 + 2InTEMPT_{ij} + InSIMTEMP_{ij} \qquad 7$$

$$InRAIN_i RAIN_j = -In2 + 2InRAINT_{ij} + InSIMRAIN_{ij} \qquad 8$$

$$InOPP_i OPP_j = -In2 + 2InOPPT_{ij} + InSIMOPP_{ij} \qquad 9$$

$$InCO2EM_iCO2EM_j = -In2 + 2InCO2EM_{ij} + InSIMCO2EM_{ij} \qquad 10$$

Where $TEMP_{i(j)t}$,$RAIN_{i(j)t}$, $OPP_{i(j)t}$ and $CO2EM_{i(j)t}$ is country i(j)'s temperature, rainfall, openness index and CO^2 emission

$$TEMPT_{ij} = TEMP_i + TEMP_j$$

$$SIMTEMP_{ij} = 1 - \frac{TEMP_i^2}{(TEMP_i+TEMP_J)^2} - \frac{TEMP_j^2}{(TEMP_i+TEMP_j)^2}$$

$$RAINT_{ij} = RAIN_i + RAIN_j$$

$$SIMRAIN_{ij} = 1 - \frac{RAIN_i^2}{(RAIN_i+RAIN_J)^2} - \frac{RAIN_j^2}{(RAIN_i+RAIN_j)^2}$$

$$OPPT_{ij} = OPP_i + OPP_j$$

$$SIMOPP_{ij} = 1 - \frac{OPP_i^2}{(OPP_i+OPP_J)^2} - \frac{OPP_j^2}{(OPP_i+OPP_j)^2}$$

$$CO2EMT_{ij} = CO2EM_i + CO2EM_j$$

$$SIMCO2EM_{ij} = 1 - \frac{CO2EM_i^2}{(CO2EM_i+CO2EM_J)^2} - \frac{CO2EM_j^2}{(CO2EM_i+CO2EM_j)^2}$$

TEMPT, RAINT, OPPT and CO2EMT are total temperature, rainfall, openness and CO2 emission of the bilateral trade partners, and they indicate the role of climatic, globalization and environmental factors in determining bilateral trade. SIMTEMP, SIMRAIN, SIMOPP and SIMCO2EM capture the degree of openness, climatic and environmental differences or similarity between the bilateral trade partner countries. Again, these variables vary from 0 to 0.5. Since D_{ij} is physical distance which is time invariant, several studies have used weighted distance to wipe-out the time-invariant nature of distance, (that is, instead of its absolute value) to measure the distance between trading partners (Nguyen, 2010; Taye, 2009). Mathematically, weighted distance is calculated as:

$$WDIS_{ijt} = \frac{DIS_{ij} * GDP_{it}}{\sum GDP_{it}}$$

Where, $WDIS_{ijt}$ is the relative (weighted) distance between trading partners, DIS_{ij} is the physical geographical distance from country i to j, GDP_{it} is the gross domestic product of country i (Nigeria) at time t and that $\sum GDP_{it}$ is the sum of all GDPs of Nigeria over the study period.

Given the link between agriculture and poverty , and agriculture's dependence on the climate, as well as the fact that majority of Africans depends on agriculture for their livelihoods, understanding the linkages between trade policies and climate change in more detail is important and urgent in the design and implementation of a free trade agreement in the continent. Increasingly, climate models over a wide range of scenarios have shown that global temperatures are expected to increase leading to longer, more frequent, and more intense temperature extremes and heat waves and increases in regional extreme precipitation events. These changes will have consequences for the average and variance of global crop yields, crop production patterns, food prices, food processing, storage, transportation and retailing (Attavanich & McCarl, 2014; IPCC, 2013; Wiebe et al., 2015). Therefore, policies for addressing the impact of climate change can influence trade policies among countries, especially in the light of recently signed African Continental Free Trade Agreement (AfCFTA), aimed at increasing intra-African trade flows. For example, trade could improve household food access by moderating price increases under climate change (Brown & Kshirsagar, 2015; Wiebe et al., 2015). In addition, trade directly impacts on emissions through the use of fossil fuels in transportation. Other indirect impacts of trade stem from its importance in terms of distribution, structure and scale of the global production and its associated GHG emissions. For instance, several studies in the literature have examine the link between trade and CO2 emission (Peters & Hertwich, 2008; Peters, Weber, Guan, &

Hubacek, 2007; Wang & Watson, 2007; Weber, Peters, Guan, & Hubacek, 2008).

3.2 Estimation Techniques

Before deciding on the estimation technique, two variants of panel unit root tests are considered. The first involves panel unit root tests with the null hypothesis of the presence of unit root with common process (Breitung, 2000; Levin, Lin, & Chu, 2002), and the second assumes the presence of unit root with individual unit root processes (Im, Pesaran, & Shin, 2003; Maddala & Wu, 1999) . In the estimation of equation 5, we used the logged value of all variables except dummies. Panel data estimation techniques are often used to capture the relationships between variables over the period of the sample because it can control for unobserved effects due to the possibility of correlation with regressors (Baier & Bergstrand, 2007). The most commonly used panel models are the fixed effects model (FEM) and the random effects model (REM). While the intercept terms are allowed to vary over the individual units but are held constant over time in the FEM, it assumes that the intercepts of individual units are randomly distributed and independent of the explanatory variables in the REM (Walsh, 2011). By default, the FEM is expected to better explain gravity model, as the panel tracks pairs of countries over time and not randomly selected. The reason why random effect model is rarely utilized in the case of gravity model is because unobserved effects are correlated with regressors making the estimates bias (Egger, 2005). However, trade between any pair of countries is prone to unobserved individual effects. In the events were these effects are correlated with the explanatory variables, it will render the result from pooled OLS to be biased. Despite the superiority of FEM over REM however, FEM cannot capture time-invariant variables which constitute an important part of the variables in a gravity equation. As a way out of this, Egger (2002, 2005) proposed the use of the Hausman and Taylor model (HTM) as a viable alternative to both FEM and REM. Hausman & Taylor's (1981) model involves partitioning the time-invariant and time-varying vector of variables in two groups each, of which one group of variables is assumed to be uncorrelated with the fixed effect model. What made the HTM model to gain popularity in the context of gravity equation is its use of instrumental variable that utilize information solely from within the dataset to eliminate correlation between the explanatory variable and the unobserved individual effect that undermines the potency of REM in the context of the gravity model. Thus, as a variant of random effect model for panel data, HTM allows us to include time-invariant variables in our model like common language, colonial ties, and geographical boundary. As such, this study utilized the FE and HT Models.

4.0 Results and Discussion

Table 1 presents the descriptive statistics for the variables used in the estimations. The result shows that there is substantial variation in the variables, as indicated in the standard deviation which suggest that the dispersion around their averages is relatively wide. Also, the kurtosis that measures the peakedness or flatness of the distribution is greater than 3 in most of the series, suggesting that the series peaked to the surface or is leptokurtic relative to the normal distribution. The skewness value indicate that all the series have more negative than positive values and thus have a longer left tail. Since all variables exhibit clear trends, all the panel data unit root tests included an intercept and a linear trend.

Table 1: Descriptive Statistics

	Xij	TEMPT	SIMTMP	SIMRAIN	SIMOPP	SIMGDP	SIMCO2EM	RAINT	OPPT	GDPT	Dij	CO2EMT
Mean	4.258	2.824	0.500	0.472	0.062	0.499	0.397	3.617	-0.629	22.274	2.054	4.673
Median	4.249	2.836	0.500	0.499	0.380	0.499	0.475	3.830	-0.505	22.248	2.200	4.770
Maximum	6.708	2.911	0.500	0.500	0.500	0.500	0.500	4.252	-0.089	23.951	2.685	6.004
Minimum	0.473	2.690	0.498	0.217	-9.163	0.495	-0.544	2.199	-2.557	20.896	0.794	2.277
Std. Dev.	1.470	0.061	0.001	0.065	1.058	0.001	0.233	0.519	0.550	0.763	0.488	0.882
Skewness	-0.320	-0.695	-1.725	-2.804	-5.642	-0.683	-3.271	-1.221	-2.686	0.352	-1.039	-0.821
Kurtosis	2.405	2.520	4.557	9.780	43.006	2.201	12.462	3.598	9.252	2.260	3.086	3.516

The results of all LLC, IPS and MW panel unit root tests suggest that, the variables are stationary at different levels. Maddala & Wu (1999) show that the MW test is more powerful than the IPS test which is in turn more powerful than the LLC test, because MW test has superior size and power property that allows for heterogeneity of cross-sectional units within the panel (Wang et al., 2010). As such, our interpretation of unit root test result in this study is based on MW panel unit root test with intercept and time trend since our data set exhibit clear trends. The result of the panel unit root test is presented in Table 2.

Table 2: Panel Unit Root Test

	Xij	TMPT	SIMTMP	SIMRAIN	SIMOPP	SIMGDP	SIMCO2EM	RAINT	OPPT	GDPT	Dij	CO2EMT
Null hypothesis: unit root (with common unit root process)												
Levin, Lin & Chu t*	-1.89^{*a}	-11.30^{***a}	-6.10^{***a}	-3.55^{***a}	-4.82^{*a}	-3.46^{*a}	-5.11^{*a}	-2.42^{*a}	-3.66^{*a}	-1.79^{*a}	-3.56^{*a}	-4.16^{*b}
Breitung t-test	-1.67^{**a}	-11.85^{***a}	-5.53^{***a}	-3.32^{**a}	-2.23^{**a}	-2.48^{*a}	-4.33^{**a}	-3.58^{*a}	-1.71^{*a}	-4.03^{**b}	-2.21^{**a}	-1.17^{**b}
Null hypothesis: Unit root (assumes individual unit root process)												
Im, Pesaran and Shin W-stat	-1.69^{**a}	-3.66^{**a}	-2.57^{***a}	-1.47^{***a}	-1.24^{*b}	-10.22^{**a}	-1.32^{*a}	-1.08^{**a}	-8.12^{**a}	-3.16^{*b}	-5.12^{*a}	-3.91^{*a}
ADF-Fisher Chi-square	76.47^{**b}	60.58^{*b}	78.13^{**b}	64.48^{**b}	62.58^{*b}	78.13^{*b}	51.85^{*b}	55.02^{*b}	125.85^{*b}	40.56^{**b}	95.16^{**b}	43.97^{**b}

Note: a and b denote stationarity at level and at first difference respectively, while ***, **, * indicate statistical significance at 1%, 5% and 10% respectively. All the variables are expressed in natural logs.

Table 3: Fixed Effect and Hausman-Taylor Regression

Table 3 shows the results of the estimated equation by fixed effect method and Hausman Taylor model. We use the model similar to that in Wang et al. (2010), where the dependent variable used in both regressions is the export of Nigeria to her trading partners. The result from both fixed effect and Hausman Taylor models shows that GDPT is positive and significant indicating that the higher the GDP of both countries, the higher the value of trade which is in line with the standard gravity model of international trade. The effect of the measure of similarity in GDP (*SIMGDP*) as shown in the fixed effect and Hausman Taylor models is also found to be positive and significant. This variable has been added in the model to capture growth or technological inequalities between countries engaged in trade. The variable has been specifically added to test the Lynda hypothesis which states that "country with similar level of income or GDP per capita exhibit similar behavior, produce similar but differentiated products amongst them". The sign is positive and significant which indicates that bilateral trade flows between Nigeria and her trading partner(s) is related to inter-country differences in the level of economic performance. The result is in line with Duc Niem (2016) who found that vertical inter-industry trade share was higher when China traded with a country with similar size or economic development.

Table 3: Fixed Effect and Hausman-Taylor Regression Results

Dependent Variable X_{ij}

	Fixed Effect	Hausman-Taylor Model
$In\ GDPT$	1.595^{**}	1.969^{*}
	1.379	12.093
$In\ SIMGDPT$	1.653^{*}	1.413^{***}
	1.042	1.160
$In\ TMT$	4.839^{**}	6.179^{*}
	2.713	4.371
$In\ SIMTMT$	3.314^{*}	2.245^{*}
	2.329	12.100
$In\ RAINT$	1.276^{*}	1.534^{**}
	7.574	1.390
$In\ SIMRAIN$	4.616^{***}	5.319^{*}
	10.692	2.826
$In\ CO2EMT$	-1.296	-0.333^{*}
	1.779	0.101
$In\ SIMCO2EM$	1.397^{**}	3.629^{*}
	0.664	2.377
$In\ OPPT$	2.399^{*}	1.481^{***}
	1.396	1.266
$In\ SIMOPP$	-0.314^{***}	-0.082^{*}
	0.106	0,976
$In\ Dij$	1.005^{***}	1.507^{*}
	0.510	0.522
Col.		2.415^{***}
		3.727
Lang		3.187^{*}
		10.037
Border		3.139^{**}
		4.074
R^2	0.739	
No. of Observation	153	153

All continuous variables are expressed in logs
Standard errors in brackets
* significant at 10%; ** significant at 5%; *** significant at 1%

However, our interest is in the impact of both climatic and environmental variables on trade flows between Nigeria and her African trading partners. Clearly, the result from the fixed effect and Hausman Taylor model shows that rainfall and temperature play a significant role in promoting trade. Also, the similarity or differences in the distribution of these climatic variables significantly affect trade in both models. For instance, a 1 per cent increase in temperature and rainfall increase trade by 4.84/1.28 per cent and 6.18/1.53 per cent for fixed effect and Hausman-Taylor estimate respectively. Furthermore, a 1 per cent increase in temperature and rainfall similarity raise export between Nigeria and her trading partners by 3.11/4.62 per cent and 2.25/5.32 per cent respectively. These results lend credence to the increasing significance of climate change adaptation friendly policies in AfCFTA treaty. Also, trade policy raise concern about environmental issue, for instance, trade directly impacts on emissions through the use of fossil fuels in transportation. Other indirect impacts of trade result from its importance in terms of distribution, structure and scale of the global production and its associated GHG emissions. From our result, 1 per cent increase in CO2 emission leads to 0.33 per cent reduction in trade flows in the HTM while it is negative but insignificant in the fixed effect regression. Also, the study found the degree of openness has a positive impact on bilateral trade between Nigeria and her trading partners. This indicates that the degree of openness of importing country's economy is critical to the growth of international trade. In addition, the similarity index (*SIMOPP*) for openness is negative and significant across the two regression models, indicating that the degree of openness defers across countries or there are still barriers impeding the free flow of goods across the 14 countries selected. Similarly, the geographical proximity variable (*Dij*) between Nigeria and her trading partners is positive and statistically significant in both models, indicating that distance between countries matters in bilateral trade flows. The result in both FE and HT models shows that a 1 per cent increase in the geographical distance between Nigeria and her trading partners lead to 1.01 per cent and 1.51 per cent increase in Nigeria's bilateral trade.

The remaining variable stands for country's time-invariant coefficient estimated in the HTM since, they are by default 0 under the fixed effect model. They include the effect of official common language, border and colonial ties all of which have positive and statistically significant effect on Nigeria bilateral trade. The coefficients from the Hausman Taylor model shows that a 1 per cent increase in colonial ties (COL), language similarity and proximity in terms of geographical boundary increases Nigeria's bilateral trade by 2.42, 3.19 and 3.14 per cent respectively. These results suggest that colonial ties, similarity in official language spoken and proximity in terms of geographical boundary with the trading partners promotes Nigeria's bilateral trade flows with the selected African countries.

5.0 Conclusion and Policy Recommendations

The objective of this paper is to analyze the impact of climatic and environmental variables on Nigeria's bilateral trade flows to 14 major trading partners in Africa using a gravity model. The paper used panel data from 2006 to 2018 and applied the fixed effect regression and Hausman-Taylor models for the analysis of the data. The result from both fixed effect and Hausman Taylor model shows that the effect of GDPT on the value of trade is positive and significant in both regression indicating that the higher the GDP of both countries, the higher the value of trade which is in line with the standard gravity model of international trade. Similarly, the effect of similarity in GDP (*SIMGDP*) as shown in the fixed effect and Hausman Taylor model is found to be positive and significant. The results of both climatic and environmental variables show that they impact trade flows between Nigeria and her trading partners. Specifically, the result from the fixed effect and Hausman Taylor model shows that rainfall and temperature play a significant role in promoting trade. Also, the similarity or differences in the distribution of these climatic variables significantly affect trade in both models. The results from the time-invariants variables which include the effect of official common language, border and colonial ties (all of which have positive and statistically significant effect on Nigeria bilateral trade) suggest that colonial ties, similarity in official language spoken and proximity in terms of sharing border with the trading partners promotes Nigeria's bilateral trade. In general, the result shows that trade can serve as a successful adaptation mechanism to climate change in Africa.

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