Trade and Climate Variability in the Economic Community of West African States (ECOWAS)

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Abstract

The study examined whether trade causes climate variability in the Economic Community of West African States (ECOWAS). Specifically, it investigated the impact of trade (% GDP) on climate variability indicators such as CO2, N2O, and PM2.5. The study followed Frankel debate on environment effect of trade with modification on the N2O variable rather than the SO2 used in Frankel (2003). The study employed random effect regression on data collected from World Bank indicators from 2010-2021. The study found that trade in ECOWAS cause climate variability (CO2, N2O). However, the trade effect on PM2.5 shows a decreasing relationship. The study observed scale, income and composition effect of growth on the time-varying behaviour of climate in the ECOWAS. Thus, the EKC theory was found to be present in ECOWAS. Thus, an appropriate carbon tax laws would help prevent cross border trade on dirty goods and carbon leakages associated with lax environmental control.

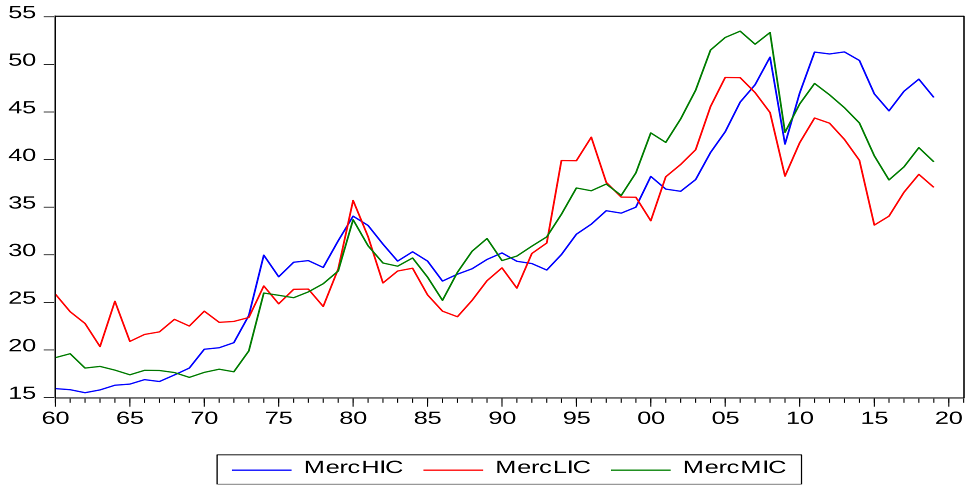
Keywords: *Trade, climate variability, carbon tax, ECOWAS*

1. Introduction

One of the drawbacks in the COP27 of 2022 which focused on climate change mitigation, adaptation and financing is that achieving "just transition" in the Economic Community of West African State (ECOWAS) has traceable cost than benefits because of the region's hitherto historical nature of fossil fuel dependency. Also, the trepidation of cross-border green house gas (GHGs) transfer due to the trade openness policy of the ECOWAS poses threats on the realization of COP27 target on global decarbonization. Another perceptible dilemma of COP27 target in the ECOWAS is the fact that the region is deeply snarled with unprecedented import of dirty goods, high reliance on fossil fuel consumption, poverty, population growths, insufficient regional control e.g., lax environmental regulation problem, cross-border carbon leakage problem, and non-disclosure issues. These issues present deep-seated challenges for ECOWAS' zero-emission targets and affect the ECOWAS' regional just transition towards a green economy.

The imperative of trade openness and global value chain (GVC) on economic growth, investment, income growth, technological progress, technical change, and technological transfer cannot be over-emphasized (see Solow, 1957; McKinonn & Shaw, 1973). Fig 1 shows the dynamic trajectory of merchandise trade (proxy for global trade) in High income countries (HIC), Low income countries (LIC), and Middle income countries (MIC).

Fig 1 : Merchandise Trade in HIC, MIC, and LIC



The questions underpinning this paper become viz; does trade improve environmental quality? What is the impact of trade openness on environmental stability in the ECOWAS? Is there causality between environmental degradation and trade? Does trade permit the global communities to achieve higher and rapid economic growth for any given level of environmental quality? Do adjustments in trade policy disrupt environmental quality or damage environmental quality for any given rate of economic growth? Therefore, the objective of this paper seeks to; investigate the environmental effect of trade, determine international trade consequences of climate change, and ascertain the relationship between trade, CO2 emissions, N2O, and PM2.5 in the ECOWAS.

Revisiting the environmental policy implication of trade in this paper would largely focus on the extent to which trade liberalization has impacted on the environmental situation in the ECOWAS. Trade (proxy by trade (%GDP)) does not distinguish between dirty and clean good in cross-border trade. The contribution of this paper is to effectively examine the impact of trade on climate change in the ECOWAS. The impossibility of cross-border GHG transfer emanating from regional trade in HIC, LIC, and MIC therefore require an in-depth study to estimate the environmental effect of trade in the ECOWAS.

There are five subsections in this paper. They are introduction, literature review, methodology, discussion and findings, conclusion, recommendation and policy implications.

2. Literature Review

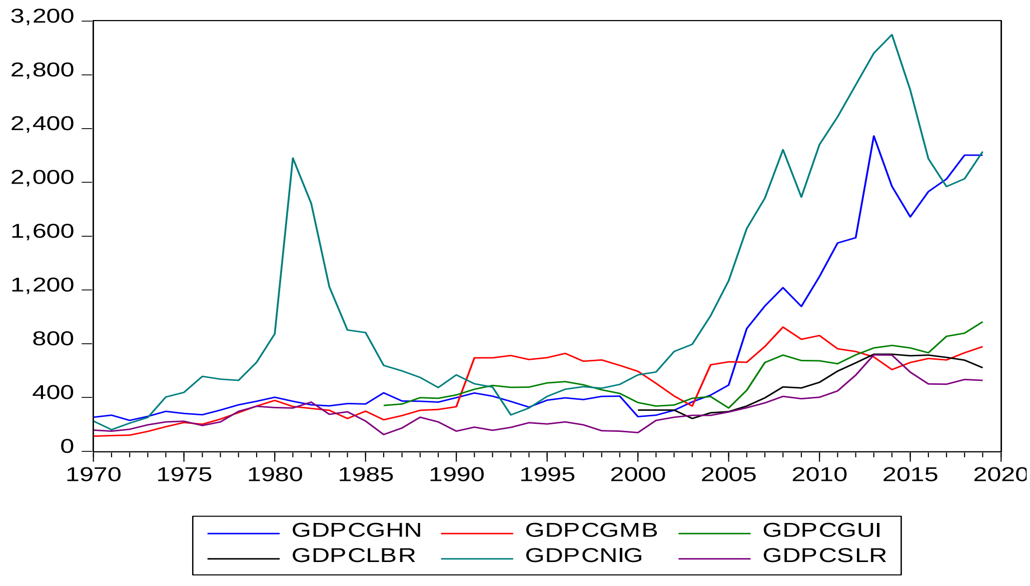
Conceptual Issues

Most of the theoretical backdrops underpinning the controversy in the trade-environment debate has been pursued through the environmental Kuznets curve (EKC), race to the bottom hypothesis, gains-from-trade hypothesis, top-down and bottom-up approach, and pollution haven hypothesis, just to mention but a few. Given the new system expressed in COP 27, the NDCs target is at a crossroad due to the inevitable, irreversible scales and consequences of climate change on the ecosystem, biodiversity, market forces (economy), financial system, and human existence. Despite the non-compliance in NDCs by developing countries e.g., sub-Saharan Africa, the COP 27 leverage the NDCs to deepen nations NDCs-sensitivity towards decarbonization solutions. But the emerging climate conditions remain challenging because of the grave danger and risks that are inextricably tied to growing the economy, expanding trade frontiers, and attaining environmental stability goals jointly in the face of the heightening trajectory of dirty good trade.

So given the climate change and problems associated with the global dimensions of lax environmental regulation scholars such as Frankel and Rose (2003) and Dean (2002) have devoted considerable studies to examine whether free trade (globalization) hamper environmental quality. Although the disagreement between Frankel and Rose (2003) and Dean (2002), Frankel (2009) further explains the difficulties of realizing COP 27 due to the internationalization of climate change. At the centre of the decarbonization debate is the issues on cross-border carbon leakage, trade on environmental goods or dirty goods into Africa, and the attendant regional lax on environmental standards in Africa. Most of the studies admits that cross-border carbon leakage creates un-priced externalities and competitiveness loss problems which scholars tries to resolve by examining amongst other issues the nexus between trade openness and environmental instability. In Africa, there are robust concerns about the issues of climate change risk and shocks, dirty goods imports, and on the other hand the dilemma regarding Africa's preparedness to meeting net-zero emissions and COP27. In this response, the AFDB's Hub template towards meeting the NDCs revolves around tripartite policy statements namely; fostering long-term climate action, mobilizing means for implementation, and coordination, advocacy, and partnerships. The intended NDCs (INDCs) in Africa are less sensitive of the long-term effects and its national developmental objectives.

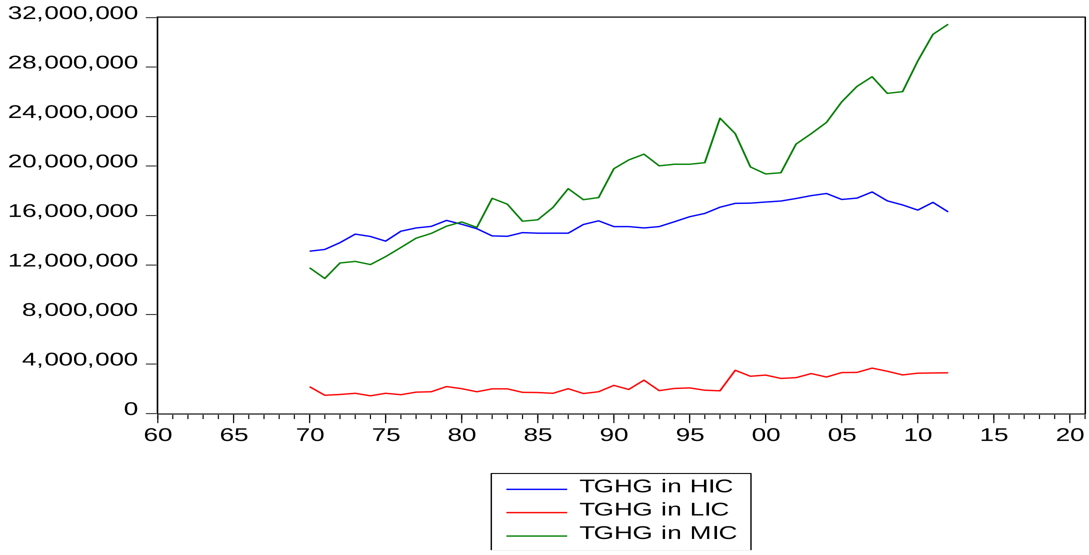
In order to expand the foregoing studies, it is imperative to admit that recent studies have failed to examine the deep-seated controversy bordering around regional NDCs taking robust attention on dirty good import into Economic Community of West Africa States (ECOWAS). Therefore, the corresponding trends in Figures 1, 2, 3, and 4 offer insight into the compelling and prevailing concern on the exigency to understand trade openness and climate change nexus in ECOWAS. Fig. 2 shows GDP trend as well as provide a glimpse into the anthropogenic activity overtime that contributes to environmental instability.

Fig 2: GDP Trends in Selected African Countries



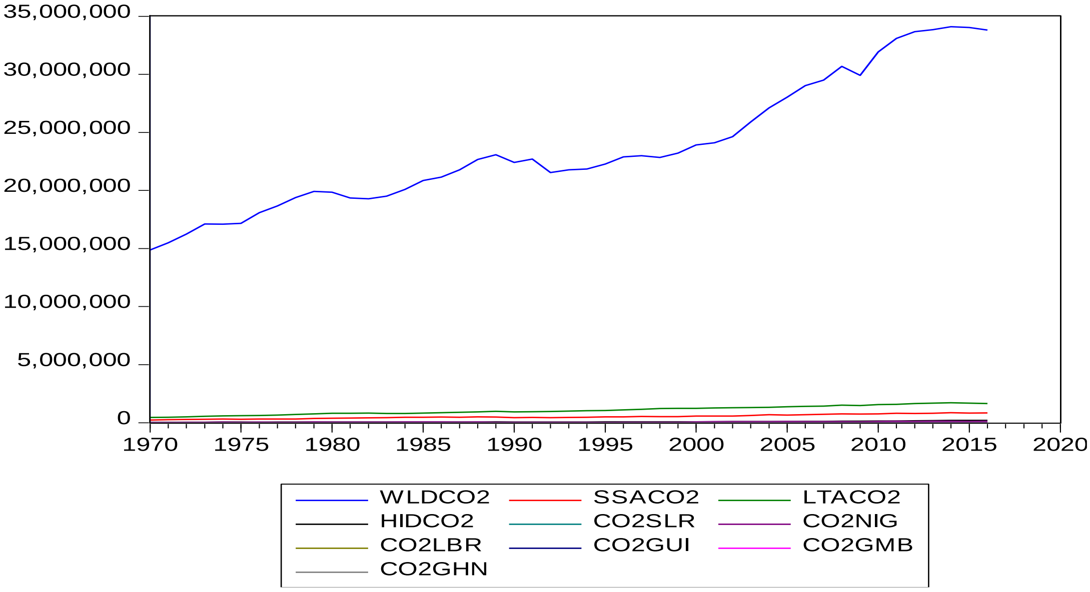
But, the possibly environmental shock expressed in Fig. 3 and 4 provides disturbing outlook consequences due to the implosive effect of global warming. Climate change (proxy as CO2, SO2, and GHG emissions) can produce severe damage to the global ecological, economic, and social system (Buch and Weigert, 2021). Climate change generates physical risks e.g., droughts, rising sea levels, and flooding that disrupts economic interactions e.g. financial mechanisms as well as cause hazards. Environmental shock is a type of externalities that introduces damaging effect on economic agents often beyond the market forces. One of the enablers of environmental pollution is greenhouse gas (GHG).Anthropogenic-GHG type is generated through income per capita and comparative advantage channels e.g., global trade and Total GHG (TGHG) emissions in low-middle-high income countries. From 1970-2020 the trend of TGHG emissions is growing raising genuine concern about the long-term consequence on the economy. So, policymakers introduce environmental policy to adjust carbon emission that causes global warming in Fig 3-4.

Fig 3 : Total GHG in Low-Middle-High Income Countries



CO2 is a major enabler of GHG emissions. In fig. 4, the trend in CO2 indicates an increasingly dilemma and burden of environmental shock. Fig. 4 connotes that World CO2 trend is increasing at an increasing rate which depicts damaging threat to the ecosystem and biodiversity. The trends in trade and GHG show that pollution is highly pro-cyclical and more volatile than GDP (Doda, 2014 in Annicchiarico, Carattini, Fischer, and Heutal, 2021).

Fig 4 : World CO2, CO2 Trends in Selected African Countries



The figures 1, 3, and 4 thus threw-up questions surrounding the NDCs effects and the implications of trade openness (global value chain) on the global environmental stability.

Fig 1 shows that the middle-income countries (MIC) relatively generate high emission than the low-income countries (LIC) and high-income countries (HIC). TGHG in the LIC is less compared to MIC and HIC. But the implosive trade-off in the environmental-trade nexus e.g. super-wicked phenomena, the trajectory of the non-excludability, and the `mutually non-excludability properties of greenhouse gas (GHG) emissions present new challenge for scholars. Scholars have rarely agreed on the real impacts of ever-changing global trade policy on the country's capacity to achieve NDCs (Copeland and Taylor, 2003; Jayadevappa and Chhatre, 1999; Taylor, 2004). In order to resolve these known and unexpected dilemmas prevailing in the trade-climate change nexus, scholars have shown robust interest on the ex-ante and ex-post implications of climate-related risk and shock on the global economic system (Angelopoulos et al., 2010; Fischer and Springborn, 2011; Heutal, 2012; Annicchiarico and Di Dio, 2014). Frankel (2009) and Dellink, Hwang, Lanzi, and Chateau (2017) squarely dealt with the implications trade and climate change. The major concern raised in the foregoing studies typifies feedback risks (exposure) prevailing between trade openness and climate change. These studies undermined the implications of import openness, export openness, net export openness, visible (invisible) export, and import dynamics in the ECOWAS on climate change vice versa. One therefore wonders the implications of the ECOWAS trade openness policies such as the African Continental free Trade Area (AfCFTA) deal, trade liberalization and other globalization policies e.g., export promotion incentives and strategies, to strengthen macroeconomic convergence criteria (MCC) and Eco currency goal on its NDCs as well as environmental stability of the ECOWAS.

The problem of NDCs is deeply situated around the determinants of trade liberalization which causes cross-border GHG transfer. Before the paper delve into problems of trade liberalization on the environment, it is pertinent to ask, what is current state of relationship between trade and environment (climate change)? Do trade policies improve climate change for any given level of economic growth? Can environmental policy on NDCs affect trade openness?

Global trade is approximately 32 times greater now than it was in 1950, and the share of trade on GDP rose from 5.5% in 1950, to 21% in 2007, and to 51.62% in 2021. Global trade hits record level of $28.5 trillion in 2021 representing an increase of 25% on 2020 and 13% higher compared to 2019, before the COVID-19 pandemic occurred. Trade in goods increased up to $200 billion with a peak of $5.8 trillion, and trade in services rose by $50 billion to reach $1.6 trillion higher than its pre-pandemic levels (UNCTAD, 2022). Whilst, new dimension of export dynamics has occurred due to an increasing export participation, the developing countries reached 30% growth and wealthy nations grew by 15% between 2020 and 2021 (UNCTAD, 2022). For example, developing countries now account for 34% of merchandize trade doubling their share in the early 1960s (WTO-UNEP, 2009). By classification, WTO (2021) attest that the share of transport-related carbon dioxide (CO2) ranges between 11.8%, 11.2%, 2%, and 72.6% for international maritime shipping, aviation, rail transport, and road transport respectively. According to WTO-UNEP (2009) the combined estimates of greenhouse gas emission is between 1.8^{o}C and 2.0^{o}C when juxtaposed with the past decade's growth of 0.74^{o}C of global average earth-surface temperature. By estimation, there are indications, ceteris paribus, that emissions will grow between 25% and 90% in the period from 2000 to 2030. The consequence of the rising emissions poses an irreversible impact on the global climate system (WTO-UNEP, 2009).

Global trade, global supply chain, and global value chain affect greenhouse gas (GHG) emissions in multiple ways, and the implications of trade on carbon emissions is complex to estimate. This equally implies that trade-related carbon emissions have environmental footprint that leads to climate change (WTO, 2021; Brenton and Chemutai, 2021). Brenton and Chemutai (2021) posit that global trade in environmental goods is estimated at more than US$1 trillion annually and is rising. CRED and UNDRR (2020) showed that the disaster impacts from climate-related uncertainties for period (2000 and 2019) relative to (1980-1999) has generated an 82.2% growth in global economic losses from 1.63 trillion to 2.97 trillion, over 4.03 billion from 3.25 billion persons were affected depicting a 24% growth, and total deaths moved from 1.19 million to 1.23 million (3.36% growth) etc. (cited in UNCTAD, 2021). To complement the CERD and UNDRR (2020) revelation on climate-related risks and uncertainties, WMO (2021) reports that between 1970 and 2019; weather, climate and water hazards accounted for 50% of all disasters, 45% of all reported deaths, and 74% of all reported economic losses, with 91% of the deaths experienced in developing countries (In Brenton and Chemutai, 2021). UNEP (2021) climate-related disaster increased by 83% in first two decades of 21st century compared to the two decades of 20th century i.e., rose from 3,656 to 6681 disaster events. Similarly, Dellink, Hwang, Lanzi, and Chateau (2017) using ENV-linkage model computed the direct impacts (see UNCTAD, 2014; OECD, 2015) and the indirect impacts (see OECD, 2015) of climate change on international trade.

The increasingly uncertainties manifesting through trade-global warming (CO2 concentration) nexus have thrown up vista of discourse on the imperative of reversing the global warming trends (Stern Review, 2006). One of the vexed policy actions to achieve net zero emission and green, resilient, and inclusive development (GRID) targets is through trade and global value channels (WTO, 2021). Several scholars have adduced that changes in trade flows and CO2 fertilization offsets productivity effects caused by climate-related uncertainties (Nelson, et al., 2009; Zhang, 2018). The positive effect of trade flows is anchored on the basic analysis that changes in trade flows through trade liberalization policy and exploitation of comparative advantage would reduce climate change cost (see ES.1: Brenton and Chemutai, 2021; Antweller, Copeland, and Taylor, 2001).

Theoretical Literature

Given the five issues presented above, the suitable theoretical framework to account for the exogenous shock and Procyclical dimensions in the trade-climate change nexus is the Real Business Cycle (RBC) framework. Without playing down on any of the contentious foregoing issues, the logic established in the sixth assessment report. IPCC (2022) provide proper guide to the reasoning pattern of this paper. IPCC (2022) admits that the coupling-system problem arises because of the increasingly adverse, interconnected, and often irreversible impacts of climate change on the human system, ecosystem, and their biodiversity. IPCC identified climate risks events measured through reference period analysis (1850-1900) and reference future periods: near term (2021-2040), mid-term (2041-2060), and long-term (2081-2100).These climate risk events have potentials to disrupt SDGs. Furthermore, another important framework is the World Bank framework (in Brenton and Chemutai, 2021).The framework provides solid environmental framework that incorporates system-wide implications of environmental shocks (pollution, externality) on economic aggregates vice-versa.

The World Bank framework graphical showed the physical and transitory risks underpinning trade and climate change. The graphical illustration depicts amongst other things how trade policies and climate policies simultaneously affect the trade-climate ecosystem. The intersection between climate change (e.g., increasing sea levels, permafrost collapse, etc.) and trade (e.g., production and consumption, distribution, and migration) provides a detailed examination that underpins the solution that influences mitigation and adaptation (in Brenton and Chemutai, 2021). Trade affect environment through real income effect, transfer effect, efficiency effect, and carbon leakage effect (Brenton and Chemutai, 2021).

To properly put this research into theoretical context, the real business cycle framework provides a rich framework to empirically understand implications of exogenous shocks on the long-run structural trajectory of the economy. The real business cycle framework is a neoclassical decision platform that curatively showed that a long-run impetus of economic modelling despite the implosive random fluctuations in the rate of technological change. In response to these fluctuations, rational economic agents alter their levels of labour supply & demand, consumption expenditure, as well as their objective function (Mankiw, 1989). According to Mankiw (1989) RBC deepen the logic on the technological disturbances (shocks). RBC holds that there is monetary neutrality and technological shock which play a key role in the extent of shock on economic landscape. The stylized facts in the RBC framework is situated around the issues of co-movement, technology innovations, and shocks depicting the interplay between economic environment and the stock variables.

Environmental Kuznets Curve (EKC) assertively provides theoretical insight into the trade and the environmental stability questions. EKC is decomposed into income approach (scale effects) and non-income approach (composition and technique effects) According to Grossman et al EKC showed that income growth per capita (economic growth and development) has dual effects on the environment through scale, composition, and technique effects. Albeit with the limitations, EKC offers an overview on the impact of economic phenomena and the environmental stability without providing clue into NDCs targets.

The EKC can be decomposed into income and non-income approach. These approaches affect the behaviour of the EKC. According to Taylor (2003) and Afesorgbor and Demena (2019) using a meta-analysis observed that the net effect of trade on environment emissions largely depends on the scale, technique, and composition effects. The results attest to the fact that trade disrupt environmental emissions. The study showed that emission-content of trade is higher in developed countries rather than in the developing countries.

Income approach: The scale effect

World Bank (1992) and Grossman and Krueger (1993, 1995) -SO2 and smoke-, Selden and Song (1994) SO2, suspended particulate matter (SPM), NOx, carbon monoxide, Shafik (1994) suspended PM and SO2, Hilton and Levinson (1998) automotive lead emissions, Bimonte (2001), showed that income per capita has dual effects-harmful effects and beneficial effects. The EKC acknowledges a controversial inverted U-relationship between income per capita and environmental stability.

Non-income approach

The non-income approach focuses on composition dimension and technique dimension of EKC. Non-income approach can be explained using the race to bottom hypothesis (negative effect), gains from trade hypothesis (positive effect), globalization and trade liberalization theory, pollution haven hypothesis, environmental policy effect etc.

Mattoo, Subramanian, van der Mensbrugghe, and He (2009) in a study "reconciling climate change and trade policy" found two important policy directions in the issue of border taxes. They are viz, implementation of carbon content of imports on merchandise imports improves competitiveness. While carbon content in domestic production-border tax if applied to both imports and exports would stimulate competitiveness concerns of manufacturers. The study employed BTADU scenario and computable general equilibrium (CGE). Managi, Hibiki, and Tsurumi (2009) studied that non-OECD's trade openness experiences is advantageous for decreasing CO2 emissions. This paper attests to the fact that the influence of scale effect largely influenced trade progress of the manufacturing capacity in the industrialized countries.

Antweiler, Copeland, and Taylor (2001) sought answer to question whether freer trade disrupts environment? The study was concerned with pollution concentration content in the market openness share on international goods. The study applied EKC theory using data on Sulfur dioxide concentrations. The study found that global trade generates relatively small changes in pollution concentrations when it alters the composition of national output. Hence, trade openness (free trade) enables environmental quality.

Brenton and Chemutai (2021) in a study entitled "the trade and climate change nexus" revealed three-dimension possibility of trade and climate change nexus. Trade disrupt climate change through income growth channel, trade provides nodes to foster and stimulate green, resilient, and inclusive development process: trade can enable production shift from dirty to clean production techniques, trade promotes distribution of environmental goods, service, and technology etc.; trade import is critical for combating climate change devastation, and trade is affected by extreme weather-related risks such as storms, floods, and drought etc. The study adopted an analytical framework and World Bank conceptual framework to x-ray the trade and climate change.

Nexus.

Dean (2003) in a study "does trade liberalization harm the environment" employed a simultaneous-equations system the study confirm that freer trade aggravates environmental damage through terms of trade channels, but mitigate environmental decay through income growth. In another related study, Frankel and Rose (2003) in a study titled "is trade good or bad for the environment; sorting out the causality? The study found that trade decelerates three measures of air pollution PM, SO2, and NO2. The study adopted cross-country equation, OLS, and IV estimates.

Low, Marceau, and Reinaud (2011) in a study to examine the interface between the trade and climate change policy regime observed that uneven cross-border mitigation enables carbon leakages hence producers considers transferring plant site to locations where production cost is least affected by emission constraints. Also, the study show that due to uneven mitigation-climate change policy, gains from trade are skewed hence reduces to competitiveness loss. Furthermore, the study found that trade relations is susceptible to climate change because the GATT/WTO rules were not calibrated to accommodate climate change risks, shocks, as well as responsive climate change policies which has resurrected issue of lax environmental regulation which affect gains from trade.

Evaluations of Literature Reviewed

In course of reviewing the literature, this paper observed five current knowledge on climate change and policy issue that affects global NDCs in relation to net zero emissions target. They are firstly, IPCC (2022) identified in its summary for policymakers (SPM) report issue of coupled-system problems that influences the climate, ecosystem, biodiversity, and human system outcomes. IPCC (2022) report tagged "climate change 2022: impacts, adaptation, and vulnerability" recognizes the interdependence of climate, ecosystem, biodiversity, and human societies called the couple system. IPCC (2022) using WGI assessment provides a 50% likelihood that global warming could reach or exceed the 1.58^{o}C. The key findings on climate-related risk especially on AR5(6), SPM.B.1.1- SPM.B.4.7 stimulates rich background on the confidence level of uncertainty, consequences, implication and disruptive tendencies of climate-related risks e.g., extreme weather, increasing sea levels, intensification of heavy precipitation, tropical cyclone, heat waves, heavy rainfall, and coastal flooding on the global supply chain, trade & transport and logistics infrastructure (see SPM.B. 4.7).

Secondly, this paper also builds on the existence of procyclical problems (Doda, 2014 in Annicchiarico, Carattini, Fischer,) and super-wicked phenomena which showed that time is running out, inadequate policy toolkit, and there exist policy contradiction between growth and climate change policy. Hence, Whist climate change transmits physical risk (shocks) on the global macroeconomic frontiers. Also, economic factors e.g., transport, trade, global supply chain via fossil-fuel utilization enables GHG emissions (concentration) that causes climate change (Dellink, et al., 2017; OECD, 2009; Copeland and Taylor, 2004; Cosbey and Tarasofsky, 2007). On the other hand, transition risk surfaces which exposes the market fundamental thereby causing huge economic damages (WTO-UNEP, 2009; Race, 2015; Dellink et al, 2017). Thus, the super-wicked problem concretizes the causality and shock literature which connotes that economic damages increases non-linearly with global warming level (IPCC, 2022).

Thirdly, there are a robust literature on the optimal dimension of the imposition of appropriate cap-and-trade policy, lax environmental regulations and dirty-good dumping (Copeland and

Taylor, 2004; Levison and Taylor, 2002), carbon leakages, and GHG cross-border transfers, and regional mitigation and optimal carbon tax policy. The major problem confronting the cap-and-trade and carbon tax policy is the presence of unexaggerated heterogeneity that causes a concurrent and regional climate hazards cascading to sectors and regions between high emitters and low emitters (IPCC 2022 SPM.B.5.1-SPM.B.5.5). This scenario gives rise to (i) pollution hypothesis issue, (ii) border tax issue: carbon content of imports or the carbon content in domestic production (Mattoo, Subramanian, van der Mensbrugghe, and He, 2009). Hence, the aforementioned issues make it increasingly difficult for an appropriate cap-and-trade, border tax, mitigation and adaptation, as well as the implementation of other appropriate environmental policy.

Fourthly, WTO/GATT was not drafted to account for the climate-related problems in I, II, and III. Hence, the issue of carbon leakages and cross-border tax adjustment (CLCBT) raises the question of the imperative of climate change mitigation policy. The issues of CLCBT often leads to the problem of competitiveness loss, defilement of the non-attainment of the United Nation Framework Convention on Climate Change (UNFCCC) principle of "common but differentiated responsibilities policy," This issue disrupt the agreement as well as causes equitable distribution of burden elusive (Low, Marceau, and Reinaud, 2011, Zhang, 2018). Kemfert and Tol (2001) pursued this line of reasoning through the equity frontier and Tol (1999) worked on intertemporal equity literature. With the logic that non-incorporation of equity and intertemporal equity issues in the climate change uncertainty model affect cost effectiveness by extension creates competitiveness loss.

Fifthly, despite international policy responses on Paris Agreement COP21, Marrakesh Agreement, United Nations Framework Convention on Climate Change (UNFCCC) 1992, Kyoto Protocol (1997): with emphasizes on emission trading, joint implementations, and clean development mechanisms; Bali Action plan (2007), Montreal Protocol, trade-related investment measures (TRIMS), trade in services (GATS), and trade-related intellectual property rights (TRIPS) (Low et al. 2011). There are robust scientific justification confirming the regional consequences of climate change (IPCC, 2021 SPM.B.1.1-4.7) as well as the anthropogenic share in the greenhouse gas emissions (GHGs) concentrations has increased thereby contributing to the greenhouse emission uncertainties that causes global warming and climate change (IPCC, 2014).

3 Methodology

To squarely situate ECOWAS in the climate-trade-NDCs debate, two major perspectives underpinning the environmental effect of trade liberalization would be examined to find out which debate best explains the trade-climate change debate. Without bias, using purposive sampling techniques, Frankel (2009) and Frankel and Rose (2003) would form the baseline model for this study. This study considers ECOWAS, which was not captured in the baseline study.

Why Random effect Model?

The Hausman test prefers the random effect model to explain the environmental effects of trade openness in ECOWAS for the models in equations 3, 4, and 5. A random effect model assumes that regressors have fixed relationship with the target variable across all observations, given that these fixed effects may change from one observation to another. It is also a statistical model in which some of the explanatory parameters that compute systematic structure of the model exhibit some form of random variation. By application, random effects regression model is applied to compute the effect of individual-specific properties such as grit or acumen that are inherently immeasurable.

Given a panel model yt=XB+c+e (1)

X is a E_iTxK matrix

B is a Kx1 matrix

C is E_iTx1 matrix associated with unobservable variables

y and e are E_iTx1 matrices

the DGP (A1) is linear

$y_{it}=B_t+ E^K{}_{j=2} B_j X_{jt} +E^s{}_{p=1}m_p Z_{pi}+d_t+e_{it}$ (2)

where i=unit of observations, t=time period, j=observed explanatory variables, P=unobserved explanatory variables. The time trend t allows for a bodily shift of the intercept over time, denoting time effects. But if the implicit assumptions of a constant rate of change is strong (=d), it is nice to employ set of dummy variables, one for each time period except reference period. In a REM, we assume the $Z_{'s}$ are uncorrelated with the X_t, that is $E[z_i/X_t]$=u, given that Xi contains a constant term, u=0.u is te random term.

Baseline Study

Whilst Frankel and Rose (2003), Frankel (2009) adopted OLS, IV technique, and Panel analyses, in this study, Panel random effect model is employed to capture the environmental effect of trade openness in ECOWAS for 15 members from 2010-2021. The unbalanced balanced panel study is utilized following the baseline model developed by Frankel and Rose (2003), with slight modifications the model for this study is given as;

CO2 = f(Trade/GDP, log RGDP per capita, Log RGDP per capita square, population, log of area per capita) (3)

N2O = f(Trade/GDP, log RGDP per capita, Log RGDP per capita square, population, log of area per capita) (4)

PM2.5 = f(Trade/GDP, log RGDP per capita, Log RGDP per capita square, population, log of area per capita) (5)

Explanation of variables

CO2 emissions: Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring. Carbon dioxide emissions from liquid fuel consumption refer mainly to emissions from use of petroleum-derived fuels as an energy source (World Bank, 2021). **N2O**: Nitrous oxide emissions are emissions from agricultural biomass burning, industrial activities, and livestock management. **PM2.5** refers to tiny particles or droplets in the air that are two and one half microns or less in width. PM2.5 could be tiny particles in the air that reduce visibility and cause the air to appear hazy when levels are elevated. **Merchandise (% GDP):** Merchandise trade as a share of GDP is the sum of merchandise exports and imports divided by the value of GDP, all in current U.S. dollars (World Bank, 2021). **RGDP per capita** measures the monetary value of produced per population. RDGP per capita accounts for the welfare performance of the people. **RGDP per capita square:** is the used to provide evidence of continued engagement of factors of production in the long-run. **Population**: population account for the total number of people living in a geographical area. **Area per capita** implies the total land area in square kilometers per capita fires expressed per 1,000 population.

From the E-views estimation, the table below shows the different results obtained from estimation of trade effect on climate variability.

Table 1: Panel Random Effect model

Variables	CO2 Emissions	N2O	PM2.5
Merchandise Trade (% GDP)	0.000939 (0.0045)	4.430614 (0.2041)	-0.136022 (0.0020)
Log RGDP per capita	12.31337 (0.0000)	-169913.4 0.0000	-246.5053 (0.4798)
Log RGDP per capita squared	-40.28466 (0.0000	599463.6 (0.0000)	852.2656 (0.4831)
Population	-1.02E-10 (0.8836)	0.000207 (0.0000)	2.99E-07 (0.0000)
Log of Area per capita	33.45722 (0.0000)	2147.240 (0.0192)	NA
Observations	150	150	150

Data: World Bank Development indicators
Source: Authors Computation from Eviews

4 Discussions of Findings

From the results above, the study observed that trade liberalization policy in ECOWAS is both a negative and positive determinants of environmental instability. The environmental effects (proxy by CO2, N2O, and PM2.5) of trade liberalization (proxy by trade (% of GDP)) show that a percentage change in trade causes a 0.094% change in CO2 emissions in ECOWAS. The p-value is less than 5%. This implies that trade in ECOWAS causes environmental instability through a rise in CO2 emissions. The likely causes to the trade effects in the rise in CO2 emissions could be traceable to dirty import of technological products from abroad. However, the infinitesimal change in CO2 emissions as trade rises in ECOWAS shows that trade liberalization policy do not largely contribute to climate variability in ECOAWS. Also, beyond CO2 emissions, N2O and PM2.35 based on World Bank's classification were employed to deepen the interactions between regional trade impacts on selected climate variability. The rise in N2O by 443% although insignificant at 5% confirms that regional trade effects could create cross-border leakages and the extent of N2O could mean that lax environmental problem exist in ECOWAS leading to movement of dirty-good industries to ECOWAS region. The 13.65% drop in PM2.5 as one percent change occur in trade implies that trade effects do not affect air quality in ECOWAS. Perhaps, most of trades in ECOWAS are largely insensitive to changes in the air quality in ECOWAS. Possible explanation to these findings could mean that non-disclosure in ECOWAS can be responsible why evidences in trade effect on air pollution remain negative

In a meta-analysis to ascertain the trade effect on the environment for 88 countries, Afesorgbor and Demena (2019) results of trade impact on CO2 emissions (proxy for environment) is consistent with the finding in this study for ECOWAS countries. However, the study showed that emission-content of trade is high in developed countries than in developing countries. Fang, Huang, ad Yang (2018) result is inconsistent with the findings in the study. The study observed that cities with openness to trade shoed less susceptibility to industrial waste-water emissions but high sulphur dioxide emissions. Managi, Hibiki, and Tsurumi (2009) study for the non-OECD's trade openness experiences is advantageous for decreasing CO2 emissions is inconsistent the findings in this paper. Furthermore, the two literature adopted in this study are Dean (2002) and Frankel and Rose (2003). Whilst Dean (2003) showed consistency with the findings in this study by attesting through a simultaneous-equation that freer trade aggravates environmental damage through terms of trade channels, on the other hand, Frankel and Rose (2003) in a study titled "is trade good or bad for the environment; sorting out the causality? The study found that trade decelerates (reduces) three measures of air pollution PM, SO2, and NO2. The study adopted cross-country equation, OLS, and IV estimates. Thus, the finding in Dean (2002) is imperative to explaining the behaviour of trade openness effect on climate variability in the ECOWAS. Furthermore, the result is consistent with EKC theory as GDP per capita and squared GDP per capita appeared with a positive and negative values. The significant values at 5% implies that environment instability could occur in the short-run but at the long-run given appropriate regulatory framework in trade in clean technology, growth could cause environmental stability in the ECOWAS. The result confirms that in the short-run, growth increase CO2 emissions by 12.3% and in the long-run growth decrease CO2 emissions by 40.28%.

5. Summary, Conclusion, Recommendations

The study found that trade causes climate variability by positively contributing to CO2 emissions and N2O. The study found a negative impact of trade on PM2.5 (proxy for air pollution). The study found that scale effect, income effect, and composition effect exist between growth and climate indicators (CO2 emissions). This study therefore concludes that free trade leads to climate variability however, the impact of trade on climate variability in ECOWAS remain largely infinitesimal. Efforts to mitigate climate variability in the ECOWAS, this paper encourages policymakers to formulate and accelerate regulatory framework (policies) in order to prevent dirty trade and lax environmental issues that could raise carbon leakages in the region. This would ensure that appropriate carbon prices (cross border tax) are instituted for dirty good trade that creates climate variability or disrupts environmental quality in the ECOWAS.

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Appendix

Dependent Variable: CO2_EMISSIONS
Method: Panel Least Squares
Date: 11/23/22 Time: 04:17
Sample (adjusted): 2010 2019
Periods included: 10
Cross-sections included: 15
Total panel (balanced) observations: 150

Variable	Coefficient	Std. Error	t-Statistic	Prob.
MERCH__TRADE____GDP_	0.000362	0.000852	0.424300	0.6720
LOGRGDPPERCAPITA	12.15227	2.663611	4.562330	0.0000
SQLOGRGDPPERCAPITA	-39.53700	9.295999	-4.253120	0.0000
POPULATION	-7.68E-10	3.81E-10	-2.016117	0.0456
C	32.58979	8.066046	4.040368	0.0001
LOG_OF_AREAPERCAPITA	-0.049655	0.020269	-2.449802	0.0155

R-squared	0.739268	Mean dependent var	0.373918
Adjusted R-squared	0.730215	S.D. dependent var	0.254117
S.E. of regression	0.131990	Akaike info criterion	-1.172998
Sum squared resid	2.508688	Schwarz criterion	-1.052573
Log likelihood	93.97487	Hannan-Quinn criter.	-1.124073
F-statistic	81.65823	Durbin-Watson stat	0.046833
Prob(F-statistic)	0.000000		

Random effect

Dependent Variable: CO2_EMISSIONS
Method: Panel EGLS (Cross-section random effects)
Date: 11/23/22 Time: 04:17
Sample (adjusted): 2010 2019
Periods included: 10
Cross-sections included: 15
Total panel (balanced) observations: 150
Swamy and Arora estimator of component variances

Variable	Coefficient	Std. Error	t-Statistic	Prob.
MERCH__TRADE____GDP_	0.000939	0.000325	2.886783	0.0045

LOGRGDPPERCAPITA	12.31337	2.469231	4.986725	0.0000
SQLOGRGDPPERCAPITA	-40.28466	8.599990	-4.684268	0.0000
POPULATION	-1.02E-10	6.93E-10	-0.146635	0.8836
C	33.45722	7.471156	4.478186	0.0000
LOG_OF_AREAPERCAPITA	-0.068932	0.063570	-1.084360	0.2800

Effects Specification

	S.D.	Rho
Cross-section random	0.160603	0.9533
Idiosyncratic random	0.035556	0.0467

Weighted Statistics

R-squared	0.441344	Mean dependent var	0.026114
Adjusted R-squared	0.421946	S.D. dependent var	0.046169
S.E. of regression	0.035102	Sum squared resid	0.177434
F-statistic	22.75225	Durbin-Watson stat	0.673529
Prob(F-statistic)	0.000000		

Unweighted Statistics

R-squared	0.733079	Mean dependent var	0.373918
Sum squared resid	2.568234	Durbin-Watson stat	0.046533

Hausman Test

Correlated Random Effects - Hausman Test
Equation: Untitled
Test cross-section random effects

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	0.350822	4	0.9863

Cross-section random effects test comparisons:

Variable	Fixed	Random	Var(Diff.)	Prob.
MERCH__TRADE____GDP_	0.000956	0.000939	0.000000	0.7420
LOGRGDPPERCAPITA	12.400971	12.313374	0.411848	0.8914

SQLOGRGDPPERCAPITA	- 40.609512	-40.284656	4.870928	0.8830
POPULATION	0.000000	-0.000000	0.000000	0.6088

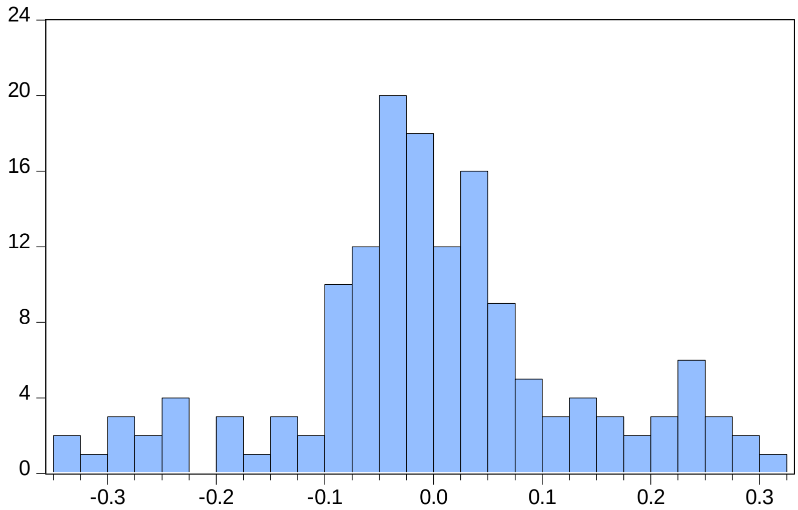
Cross-section random effects test equation:
Dependent Variable: CO2_EMISSIONS
Method: Panel Least Squares
Date: 11/23/22 Time: 04:18
Sample (adjusted): 2010 2019
Periods included: 10
Cross-sections included: 15
Total panel (balanced) observations: 150
WARNING: estimated coefficient covariance matrix is of reduced rank

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	33.39749	7.722242	4.324844	0.0000
MERCH__TRADE____GDP_	0.000956	0.000330	2.902048	0.0044
LOGRGDPPERCAPITA	12.40097	2.551264	4.860716	0.0000
SQLOGRGDPPERCAPITA	-40.60951	8.878669	-4.573829	0.0000
POPULATION	1.34E-10	8.32E-10	0.160858	0.8725
LOG_OF_AREAPERCAPITA	NA	NA	NA	NA

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.982788	Mean dependent var	0.373918
Adjusted R-squared	0.980423	S.D. dependent var	0.254117
S.E. of regression	0.035556	Akaike info criterion	-3.717531
Sum squared resid	0.165612	Schwarz criterion	-3.336184
Log likelihood	297.8148	Hannan-Quinn criter.	-3.562601
F-statistic	415.5451	Durbin-Watson stat	0.721853
Prob(F-statistic)	0.000000		



Series: Standardized Residuals
Sample 2010 2019
Observations 150

Mean	7.87e-15
Median	-0.009438
Maximum	0.300537
Minimum	-0.336152
Std. Dev.	0.131288
Skewness	-0.062568
Kurtosis	3.365085
Jarque-Bera	0.930912
Probability	0.627849

Residual Cross-Section Dependence Test
Null hypothesis: No cross-section dependence (correlation) in residuals
Equation: Untitled
Periods included: 10
Cross-sections included: 15
Total panel observations: 150
Note: non-zero cross-section means detected in data
Cross-section means were removed during computation of correlations

Test	Statistic	d.f.	Prob.
Breusch-Pagan LM	215.1390	105	0.0000
Pesaran scaled LM	7.600311		0.0000
Pesaran CD	-0.237412		0.8123

EQUATION 2

Dependent Variable: N2O_EMISSIONS
Method: Panel Least Squares
Date: 11/23/22   Time: 04:48
Sample (adjusted): 2010 2019
Periods included: 10
Cross-sections included: 15
Total panel (balanced) observations: 150

Variable	Coefficient	Std. Error	t-Statistic	Prob.

MERCH__TRADE____ GDP_	-28.64443	12.86652	-2.226276	0.0275
LOGRGDPPERCAPITA	153315.0	40206.54	3.813184	0.0002
SQLOGRGDPPERCAPITA	-545908.7	140320.8	-3.890434	0.0002
C	472542.7	121754.9	3.881097	0.0002
LOG_OF_AREAPERCAPITA	3114.986	305.9575	10.18111	0.0000
POPULATION	0.000176	5.75E-06	30.53204	0.0000

R-squared	0.952518	Mean dependent var	6315.867
Adjusted R-squared	0.950870	S.D. dependent var	8988.628
S.E. of regression	1992.361	Akaike info criterion	18.07121
Sum squared resid	5.72E+08	Schwarz criterion	18.19163
Log likelihood	-1349.340	Hannan-Quinn criter.	18.12013
F-statistic	577.7508	Durbin-Watson stat	0.053120
Prob(F-statistic)	0.000000		

Random Effects

Dependent Variable: N2O_EMISSIONS
Method: Panel EGLS (Cross-section random effects)
Date: 11/23/22 Time: 04:49
Sample (adjusted): 2010 2019
Periods included: 10
Cross-sections included: 15
Total panel (balanced) observations: 150
Swamy and Arora estimator of component variances

Variable	Coefficient	Std. Error	t-Statistic	Prob.
MERCH__TRADE____ GDP_	4.430614	3.472720	1.275834	0.2041
LOGRGDPPERCAPITA	-169913.4	26615.91	-6.383905	0.0000
SQLOGRGDPPERCAPITA	599463.6	92672.08	6.468653	0.0000
C	-537375.5	80564.72	-6.670110	0.0000
LOG_OF_AREAPERCAPITA	2147.240	907.0333	2.367323	0.0192
POPULATION	0.000207	7.94E-06	26.09297	0.0000

Effects Specification

	S.D.	Rho

Cross-section random		2348.137	0.9748
Idiosyncratic random		377.6996	0.0252

Weighted Statistics

R-squared	0.855124	Mean dependent var	320.8447
Adjusted R-squared	0.850094	S.D. dependent var	1011.949
S.E. of regression	391.8032	Sum squared resid	22105406
F-statistic	169.9912	Durbin-Watson stat	0.603054
Prob(F-statistic)	0.000000		

Unweighted Statistics

R-squared	0.896408	Mean dependent var	6315.867
Sum squared resid	1.25E+09	Durbin-Watson stat	0.010689

Hausman Test

Correlated Random Effects - Hausman Test
Equation: Untitled
Test cross-section random effects

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	14.954934	4	0.4048

Cross-section random effects test comparisons:

Variable	Fixed	Random	Var(Diff.)	Prob.
MERCH__TRADE____ GDP_	5.737490	4.430614	0.196230	0.0032
LOGRGDPPERCAPITA	-175130.853415	-169913.421835	26078017.479522	0.3069
SQLOGRGDPPERCAPITA	620433.682233	599463.570450	307326660.413395	0.2316
POPULATION	0.000215	0.000207	0.000000	0.0580

Cross-section random effects test equation:
Dependent Variable: N2O_EMISSIONS
Method: Panel Least Squares
Date: 11/23/22 Time: 04:49
Sample (adjusted): 2010 2019
Periods included: 10

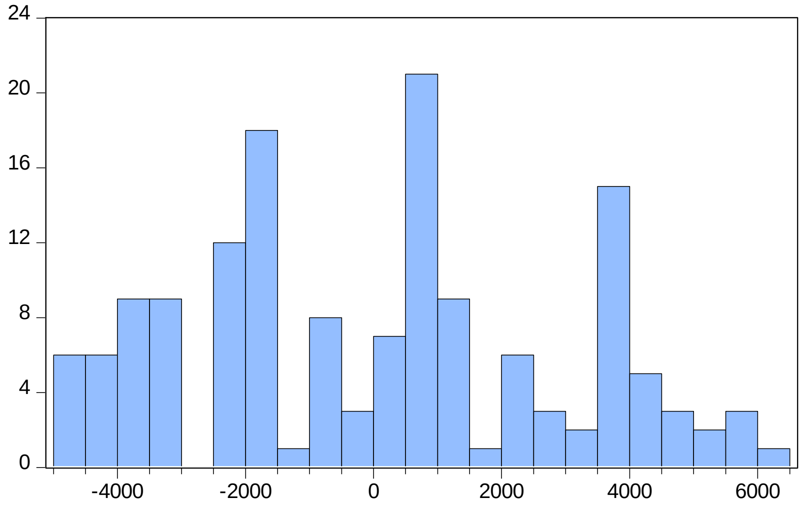
Cross-sections included: 15
Total panel (balanced) observations: 150
WARNING: estimated coefficient covariance matrix is of reduced rank

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-547256.4	82031.24	-6.671317	0.0000
MERCH__TRADE____GDP_	5.737490	3.500859	1.638881	0.1036
LOGRGDPPERCAPITA	-175130.9	27101.37	-6.462065	0.0000
SQLOGRGDPPERCAPITA	620433.7	94315.65	6.578269	0.0000
LOG_OF_AREAPERCAPITA	NA	NA	NA	NA
POPULATION	0.000215	8.84E-06	24.27845	0.0000

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.998448	Mean dependent var	6315.867
Adjusted R-squared	0.998234	S.D. dependent var	8988.628
S.E. of regression	377.6996	Akaike info criterion	14.82397
Sum squared resid	18688067	Schwarz criterion	15.20532
Log likelihood	-1092.798	Hannan-Quinn criter.	14.97890
F-statistic	4680.937	Durbin-Watson stat	0.723032
Prob(F-statistic)	0.000000		



Series: Standardized Residuals
Sample 2010 2019
Observations 150

Mean	-2.73e-10
Median	164.6715
Maximum	6098.624
Minimum	-4734.827
Std. Dev.	2893.053
Skewness	0.203138
Kurtosis	2.017663
Jarque-Bera	7.062794
Probability	0.029264

Residual Cross-Section Dependence Test
Null hypothesis: No cross-section dependence (correlation) in residuals

Equation: Untitled
Periods included: 10
Cross-sections included: 15
Total panel observations: 150
Note: non-zero cross-section means detected in data
Cross-section means were removed during computation of correlations

Test	Statistic	d.f.	Prob.
Breusch-Pagan LM	213.6986	105	0.0000
Pesaran scaled LM	7.500915		0.0000
Pesaran CD	0.488159		0.6254

EQUATION 3

Dependent Variable: PM2_5
Method: Panel Least Squares
Date: 11/23/22 Time: 05:04
Sample (adjusted): 2010 2017
Periods included: 8
Cross-sections included: 15
Total panel (balanced) observations: 120

Variable	Coefficient	Std. Error	t-Statistic	Prob.
MERCH__TRADE____ GDP_	-0.317754	0.067918	-4.678521	0.0000
LOGRGDPPERCAPITA	1373.987	217.0982	6.328874	0.0000
SQLOGRGDPPERCAPITA	-4876.297	758.6888	-6.427269	0.0000
C	4363.470	661.7935	6.593402	0.0000
POPULATION	1.63E-07	2.72E-08	6.015949	0.0000

R-squared	0.579678	Mean dependent var	34.84263
Adjusted R-squared	0.565058	S.D. dependent var	15.50451
S.E. of regression	10.22525	Akaike info criterion	7.528370
Sum squared resid	12023.90	Schwarz criterion	7.644516
Log likelihood	-446.7022	Hannan-Quinn criter.	7.575538
F-statistic	39.64989	Durbin-Watson stat	0.316010
Prob(F-statistic)	0.000000		

Fixed Effects

Dependent Variable: PM2_5

Method: Panel Least Squares
Date: 11/23/22 Time: 05:04
Sample (adjusted): 2010 2017
Periods included: 8
Cross-sections included: 15
Total panel (balanced) observations: 120

Variable	Coefficient	Std. Error	t-Statistic	Prob.
MERCH__TRADE____ GDP_	-0.074007	0.045143	-1.639383	0.1042
LOGRGDPPERCAPITA	-810.9293	424.4108	-1.910718	0.0589
SQLOGRGDPPERCAPITA	2929.976	1470.856	1.992021	0.0491
C	-2617.972	1274.238	-2.054540	0.0425
POPULATION	8.25E-07	1.45E-07	5.695994	0.0000

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.938766	Mean dependent var	34.84263
Adjusted R-squared	0.927853	S.D. dependent var	15.50451
S.E. of regression	4.164536	Akaike info criterion	5.835382
Sum squared resid	1751.680	Schwarz criterion	6.276735
Log likelihood	-331.1229	Hannan-Quinn criter.	6.014618
F-statistic	86.02301	Durbin-Watson stat	1.690618
Prob(F-statistic)	0.000000		

Random Effects

Dependent Variable: PM2_5
Method: Panel EGLS (Cross-section random effects)
Date: 11/23/22 Time: 05:05
Sample (adjusted): 2010 2017
Periods included: 8
Cross-sections included: 15
Total panel (balanced) observations: 120
Swamy and Arora estimator of component variances

Variable	Coefficient	Std. Error	t-Statistic	Prob.
MERCH__TRADE____ GDP_	-0.136022	0.043107	-3.155416	0.0020
LOGRGDPPERCAPITA	-246.5053	347.7021	-0.708955	0.4798

SQLOGRGDPPERCAPITA	852.2656	1211.396	0.703540	0.4831
C	-700.8127	1054.252	-0.664749	0.5075
POPULATION	2.99E-07	6.50E-08	4.606513	0.0000

Effects Specification

	S.D.	Rho
Cross-section random	10.15098	0.8559
Idiosyncratic random	4.164536	0.1441

Weighted Statistics

R-squared	0.213063	Mean dependent var	5.001535
Adjusted R-squared	0.185691	S.D. dependent var	5.311850
S.E. of regression	4.793363	Sum squared resid	2642.278
F-statistic	7.784049	Durbin-Watson stat	1.140193
Prob(F-statistic)	0.000014		

Unweighted Statistics

R-squared	0.149914	Mean dependent var	34.84263
Sum squared resid	24317.88	Durbin-Watson stat	0.123889

Hausman Test

Correlated Random Effects - Hausman Test
Equation: Untitled
Test cross-section random effects

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	41.350989	4	0.0500

Cross-section random effects test comparisons:

Variable	Fixed	Random	Var(Diff.)	Prob.
MERCH__TRADE____GDP_	-0.074007	-0.136022	0.000180	0.0000
LOGRGDPPERCAPITA	-810.929269	246.505279	-59227.777214	0.0204
SQLOGRGDPPERCAPITA	2929.976419	852.265641	695937.877468	0.0128
POPULATION	0.000001	0.000000	0.000000	0.0000

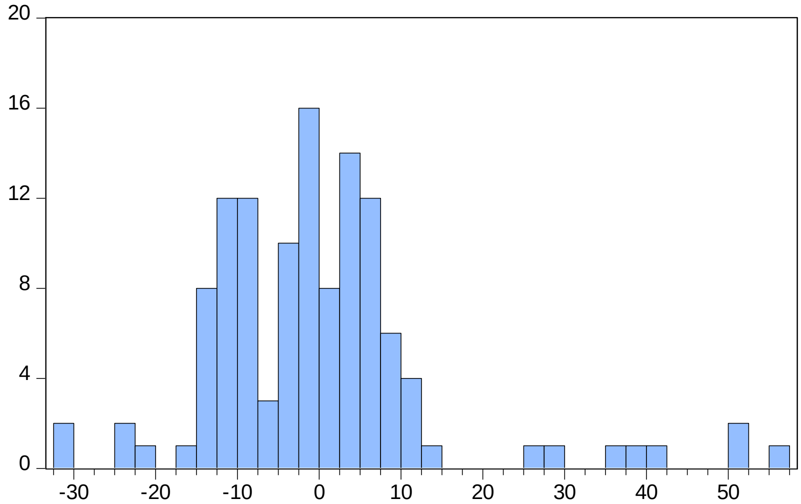
Cross-section random effects test equation:
Dependent Variable: PM2_5
Method: Panel Least Squares
Date: 11/23/22 Time: 05:06
Sample (adjusted): 2010 2017
Periods included: 8
Cross-sections included: 15
Total panel (balanced) observations: 120

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-2617.972	1274.238	-2.054540	0.0425
MERCH__TRADE____GDP_	-0.074007	0.045143	-1.639383	0.1042
LOGRGDPPERCAPITA	-810.9293	424.4108	-1.910718	0.0589
SQLOGRGDPPERCAPITA	2929.976	1470.856	1.992021	0.0491
POPULATION	8.25E-07	1.45E-07	5.695994	0.0000

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.938766	Mean dependent var	34.84263
Adjusted R-squared	0.927853	S.D. dependent var	15.50451
S.E. of regression	4.164536	Akaike info criterion	5.835382
Sum squared resid	1751.680	Schwarz criterion	6.276735
Log likelihood	-331.1229	Hannan-Quinn criter.	6.014618



Series: Standardized Residuals
Sample 2010 2017
Observations 120

Mean	1.79e-13
Median	-1.392570
Maximum	57.42643
Minimum	-32.27215
Std. Dev.	14.29517
Skewness	1.561840
Kurtosis	7.341852
Jarque-Bera	143.0452
Probability	0.000000

Residual Cross-Section Dependence Test

Null hypothesis: No cross-section dependence (correlation) in residuals
Equation: Untitled
Periods included: 8
Cross-sections included: 15
Total panel observations: 120
Note: non-zero cross-section means detected in data
Cross-section means were removed during computation of correlations

Test	Statistic	d.f.	Prob.
Breusch-Pagan LM	445.9697	105	0.0000
Pesaran scaled LM	23.52915		0.0000
Pesaran CD	20.25218		0.0000