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Determinants of Greenhouse Gas Emissions

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ABSTRACT

This paper examined the determinants (decomposed into enablers and de-enablers) of global greenhouse gas (GHG) emissions to deepen the debate on enhancing the implementation of the social cost of carbon or carbon pricing. Data from world development indicators were utilized in this study. The study leverages the autoregressive distributive lag model, pairwise granger causality, and impulse response function tests. This study found that there is a long-run relationship between selected economic indicators and GHG emissions in the global economy. In the long run, the GHG emissions enablers are FDI inflow and fossil fuel consumption. On the other hand, de-enablers of GHG emissions are GDP growth rate and merchandise trade. However, gas, oil, and coal use for electricity and fertilizer consumption have mixed finding across the regions. Also, the study observed that there exists no causality between GHG emissions and selected finance-related variables. A 1% shock in GHG emissions generates monetary volatility. Based on the findings that global trade generates a similar impact on GHG emissions across high-income countries, low-income countries, and middle-income countries. This study recommends the imposing of carbon tax and cap-and-trade on the GHGs polluting sectors and countries involved in the production and distribution of economic goods (activities) enabling GHG emissions.

Keywords: climate change, greenhouse gas, social cost of climate change, global possibility decoupling fontier

INTRODUCTION

To achieve Nationally Determined Contributions (NDCs) targets, issue of factors stimulating global greenhouse gas (GHG) emissions should be explicitly resolved. Environmental Kuznets Curve (EKC) provides information concerning the nexus between carbon dioxide (CO_2) e.g., of GHG emissions and economic growth. But the prevailing conditions underpinning the connection between business cycle (fluctuation in economic numbers) and GHG emissions has become a major policy concern. Evidence from COVID-19 disruption has recently shown that economic slow-down is associated with a decline in GHG (e.g., CO_2) emissions. In other words, CO_2 emissions are highly procyclical. In real terms, climate risk accelerates business cycle fluctuation through total factor productivity (Alam et al., 2016; Andersson et al., 2020; Bekhet et al., 2017; Nordhaus, 2017).

Andersson et al. (2020) using the new area-wide model (NAWM) found that climate risks complicate the correct identification of shocks. Given, the staggering linkage between GHG emissions and business cycle, this paper observed that the global economy contracted by a staggering 4.3% (estimated) in 2020 (UNCTAD, 2020). According to WTO (2020a), global trade plunged between 13% and 32% in 2020 due to the COVID-19 pandemic. The disruption in aggregate productivity and the global supply chain resulted in a decline in global trade (WTO, 2020b). Furthermore, as the world navigates toward a post-COVID-19 era the global agenda to stimulate the global economy in line with reversing climate change trends remain a top policy priority. Evidence proves that growth targets have climate change footprints (Bauer and Rudebusch, 2020; UNEP, 2015, 2020; WTO-UNEP, 2009). So, a policy shift to growing the global economy post-COVID-19 has climate change consequences and vice versa. However, the risks associated with the emerging trends in GHG emissions paradoxically set new rules that affect global efforts to resiliently accelerate productivity. Despite the global awareness to reduce GHG emissions, the rising industrial emission (pollution) in producing goods for net exports, tend to stimulate global warming which leaves the global economy worse off.

According to Su et al. (2016), the difference in the enablers of GHG emissions for the period between 1990 and 2017 is attributed to economic factors, demographic factors, climatic factors, and behavioral compositional arrangement of the individual country. Su et al. (2016) succinctly gave a staggering revelation of the causation existing in the cross-border GHG emissions. Conversely, the economic losses from unpredictable weather events, despite several global policies and programs to reduce environmental degradation, GHG emissions have increased in recent times, motivating the exigency in this paper to reconsider the causality between economic indicators and GHG emissions that could be leveraged to enhance the imposition of the appropriate emission tax. Rationalizing the abatement cost of GHGs emissions between high and low emitters (polluters) is one puzzling narrative that affects trade and the economic sector within the value-chain production process.

In the sense that industrialized countries transfer finished (industrial) goods that substantially generate GHGs to non-industrialized countries. In a similar vein, non-industrialized countries transfer primary products with minimal GHG emissions to industrialized countries. Similarly, the industrialized and non-industrialized countries depend on a large amount of fossil fuel to power its economic growth.

World Meteorological Organization's (WMO, 2019) Greenhouse Gas Bulletin posits that GHG emission is the substance that goes into the atmosphere (global phenomenon). Also, the report opines that GHG concentrations connote the substance that remains in the atmosphere (externality/pollution) after the complex system of interactions between the atmosphere, biosphere, lithosphere, cryosphere, and the oceans. Thus, UNFCCC (1994, 2015) sees climate change as a long-term statistical alteration of the global atmosphere and natural climate caused by indirect and direct human activity.

In 2019, GHG concentration reached new heights CO_2 (410.5±0.2 ppm) equals 148% of preindustrial levels of 1,750, methane (1,877±2 ppb) 260% of preindustrial levels, and nitrous oxide (332.0±0.1 ppb) 123% of preindustrial levels (WMO, 2020). The global average atmospheric CO_2 in 2018 was 409.8±0.1 ppm, which is an increase of 2.5±0.1 ppm from (407.8 ppm) and 405.5 ppm in 2017. Built on the El Nino events, the rate increase in CO_2 can be averagely decomposed into namely; 1.42 ppm/yr, 1.86 ppm/yr, and 2.06 ppm/yr for 1985-1995, 1995-2005, and 2005-2015, respectively.

Between 2009 and 2018, the CO_2 concentration has been 2.3 ppm (Lindsey, 2020). Global levels of CO_2 outpaced the 400 ppm benchmarks in 2015. Similarly, methane (CH_4) and nitrous oxide (N_2O) are attributed to factors such as agricultural biomass burning which reached a new high of about 1,869 ppb and 333.1 ppb in 2018 representing 259% and 123% of the pre-industrial level respectively (WMO, 2019). Other economic activities such as transportation, migration, remittance, agricultural production, and the population also constitute a major environmental degradation issue in the climate change and economic activities debate (Rahman, 2012). In all of these trajectories, economic activity globally creates an environmental footprint that reduces biodiversity and environmental resilience.

The motivating questions is that what are the determinates of GHG emissions? The aim of the paper is to identify the determinants in GHG emissions.

Specifically, the paper seeks to;

1. determine the enablers and de-enablers of GHG emissions (a proxy for climate change) and
2. investigate the impact of GHG emissions shock on finance-related variables in high-income countries (HICs), low-income countries (LICs), and middle-income countries (MICs).

This paper is divided into five parts viz; introduction, literature review, data and methodology, results and discussion, and conclusion and recommendations.

LITERATURE REVIEW

Theoretical Literature

There are syntheses of theories that would provide solid backdrop to the insight into factors influencing the dynamics of GHG emissions. Given the foregoing, EKC therefore implicate economic growth (income per capita) as a precursor to environmental degradation especially in the early stage. The EKC hypothesis opines that at a later stage, ratio of environmental degradation to economic growth targeting by economies (income per capita) lessen. EKC, therefore, conceptualizes an inverted-U dimension of income per capita and the environment. This implies that environmental degradation rises in the early stage of development, but at the later stage of development, environment degradation declines. According to the business cycle theory, economic activities corresponds to boom, recovery, recession, and depression phases.

Recent studies showed that COVID-19 phenomenon slowed growth and GHG (global warming). This scenario therefore suggests that dynamics in growth (trade, transport) and environment degradation is directly related. Thus, the synthesis of the real business cycle (Hautel and Fischer, 2013), EKC, Pigouvian tax, double-divided literature could deepen the rationality of carbon tax imposition on economic sectors that constitute a major pioneer to GHG emissions.

Plass (1955) in the carbon dioxide theory of climate change states that the mean surface temperature of the earth jumped by 3.6^{o}C whenever CO_2 concentration is reproduced by doubling. Also, dropped by 3.8^{o}C if the amount of CO_2 concentration is halved. The theory showed that the CO_2 equilibrium is measured with and without $CaCo_3$ equilibrium, thus, when total CO_2 is reduced less than the critical value, there exist the continuous climate oscillation between a glacial and an inter-glacial stage.

Willett (1949) provides a statistical criticism of CO_2 theory. Other theoretical synthesis that could provide a leeway to the imposition of carbon tax on emitting sectors is the Heckscher-Ohlin model (HOM) and the Schumpeter innovation theory (SIT). HOM reveals that resource endowment should be utilized as a point of reference for trade relations, as well as SIT contention that endogenous manipulation of resources drives growth gives a clue to the heightening dimension of GHG emissions. SIT views resources manipulation as the anchor for creative destruction that provides a tech pathway that improve growth perhaps at the expense of environmental quality. So, the task becomes as country manipulate its resource-base it enables GHG emissions, but the efforts to decouple environmental resources from the GHG emissions revolves around the imposition of carbon tax.

Empirical Literature

Studies that connect economic activities (e.g., GDP) and the environment debate include Chien and Sadiq (2022), Gonzalez-Sanchez and Martin-Ortega (2020), and Sterpu et al. (2018), which observed a similar positive relationship between GDP and per capita GHG emission (environmental degradation). Amaefule and Ebelebe (2022), in a study titled climate change scarce and FDI migration, found that FDI migration affects CO_2 emissions' trend in Sierra Leone and Nigeria differently. Hence, there is the presence of pollution haven hypothesis in Sierra Leone, and existence of pollution haven-halo hypothesis in Nigeria.

According to Amaefule et al. (2022), in a study to investigate pairwise causality and co-integration links between fossil-fuel consumption, CO_2 emissions, and economic growth (1960-2019) found that RGDP is a determinates of CO_2 emissions in HICs, and RGDP is not a determinant of CO_2 in LICs. Also, in a correlation instrument, Cederborg and Snobohm (2016) found a positive correlation between per capita GDP and per capita CO_2 emission. However, Ameyaw and Yao (2018) employed a causality tool and found that there exists a unidirectional relationship between GDP and CO_2 emission in five west African countries. Balogh and Jambor (2017) found the presence of EKC theory in CO_2, GDPPC, and GDPPC2 relationships.

Balogh and Jambor's (2017) CO_2 model also revealed that agricultural land productivity increases CO_2 emission. Conversely, Janike et al. (2020) asserted that climate change has a damaging role on agriculture and food security. On the other hand, the study further revealed that agriculture contributes between 10% and 14% of global anthropogenic GHG emissions.

Literature is consistent in the trade-environment nexus. Sun et al. (2019) found that trade has a dual impact on CO_2 as well as there exists a long-run causal effect between trade and CO_2 emission. Secondly, the result showed that trade openness permitted dual impacts on environmental pollution, but the effect varied across the panel. Thirdly, the study found an inverted U-shaped relationship between trade and carbon emissions which supports EKC. Zhang et al. (2017) found a significant negative relationship between trade openness and emissions. The study found a unidirectional short-run causality between emission and trade openness. Balogh and Jambor (2017) found a positive relationship between CO_2 and international trade.

One of the stimulants of growth is the foreign direct investment (FDI). The pollution halo-haven hypothesis is premised on FDI inflow. Sarkodie and Leirvik (2020) using dynamic heterogeneous estimation technique support pollution haven hypotheses in Africa. The study holds that renewable energy intensity reduces climate change in Sub-Saharan Africa, and income level worsens pollution which affects climate change.

Bauer and Rudebusch (2020) the ARDL study find that FDI is sensitive to temperature fluctuation and precipitation changes. Temperature and precipitation have a long-run negative and positive impact respectively on global aggregate FDI flows. Khan et al. (2020) posit that remittances into BRICS are the source of environmental degradation. However, in India, remittance reduced climate-CO_2 emission. The study revealed that FDI inflow increases CO_2, which aligns with the pollution haven hypothesis. According to Li et al. (2019), FDI has an insignificant influence on environmental performance for panel study between 1990-2014. Zhou et al. (2018) found that FDI increases carbon emissions in China.

Similarly, Vinh (2015) found that FDI causes a rise in pollution-GHG emissions. The result supports the pollution haven hypothesis for Vietnam. Zhu et al. (2016) obtained that the FDI effect on climate change is negative in countries with medium and high carbon emissions. Atici (2012) showed that FDI is favorable to Asian countries because there exists an inverse (decreasing) functional relationship linking FDI and climate change.

The population is used as a key sociological-anthropogenic effect in the climate change gamut. Population size affects migration, transport, and fuel uses. Shi (2001) found that population growth and income growth have an increasing impact on emissions. However, income level proved to possess a monotonically upward shift in emissions. Dietz and Rosa (1994) in transformed PAT found that the population is a positive contributor to CO_2 emissions. The transport sector causes 7.0 $GtCO_2eq$ of GHG emissions (Sims et al., 2014). Climate change (CO_2 emission) accelerates migration (Brown, 2008; Brown and Das, 2020; McLeman, 2011; UNCHR, 2009).

Balogh and Jambor (2017) found a positive relationship between tourism and CO_2. Unlike, the PAT studies; fossil fuel and energy use remain core in the GHG emissions generation. Ruijven and Vuuren (2009) examined two transmission scenarios with and without climate policy in the fuel price-GHG emission nexus. The study adopted TIMER global energy model and found that fuel price-transport-GHG emission leads to global warming. Balogh and Jambor (2017) found a positive impact of energy decomposed into coal, nuclear energy, and renewable energy production on CO_2. Gonzalez-Sanchez and Martin-Ortega (2020) similarly found that final energy intensity is a core driver of GHG emissions.

DATA AND METHODOLOGY

Data

This study employed secondary data from 1960 to 2019. The time-series data for this study was sourced from world development indicators (WDI). Data were structured into HICs, LICs, and MICs (HLM) based on world bank classification. These data are imperative for empirical evaluation of climate change because climate change generated by GHGs emissions is aggregately concentrated over a process of time. Specifically, due to the paucity of data, the study could not regionalize market capitalization (MKCAP) and value of traded stock (VST). The data presented for MKCAP and VST is in its world nature. World nature means the total of countries used in WDI analyses (Brunniermeier and Landau, 2020; Campiglio, 2016; De Haas and Popov, 2019; Dietrich et al. 2021a, 2021b).

Model Specification

This paper augmented the study by Sun et al. (2019), which focused on determinants of CO_2 to reflect the cross-border growth indicators and climate change nexus. In a simplified sense, the dynamic integrated climate-economy model (DICE) model propounded by Nordhaus (1993) conceptualizes the DICE. The DICE model utilizes the neoclassical Ramsey growth model. It explains climate change in the framework of economic growth theory. The DICE model is a typical example of a neoclassical energy-economy-environment model. But the DEFINE model links finance-related variables as core explanatory variables in the climate change debate (Dafermos et al., 2018). In this study, the synthesis of DICE-DEFINE model represents a time-framed model that augments the impact of economic variables on climate change, and the feedback impact of climate change on the economy through monetary transmission channels.

The assumption for employing the DICE-DEFINE model is based on the fact that the dual nature of growth, finance, and climate change exists in the literature. The analytical framework underpinning the DICE-DEFINE model connects climate change models to global economic performance. Other models include Nordhaus and Yang (1996) regional integrated model of climate change and the economy (RICE), the IPAT model (Ehrlich and Holdren, 1971). Thus,

$$MP \uparrow\rightarrow FSD \uparrow\rightarrow Prod\&Trade \uparrow\rightarrow GDP \uparrow\rightarrow CO2 \uparrow\rightarrow GHG\ em \uparrow\rightarrow FSD \downarrow\ economy \downarrow,$$

where, MP is monetary policy, FSD is financial sector development, Prod is productivity, GDP is gross domestic product, CO_2 is carbon dioxide, GHG is geenhouse gas emission, ↓ is decline, and ↑ is increase.

$$InTGHG_{it\omega} = \beta_o + \beta_1 FFC_{t-1} + \beta_2 GDPgr_{t-1} + \beta_3 FDI_{t-1} + \beta_4 MercTade_{t-1} + \beta_5 GOC_t + \beta_6 FertCons_{t-1} + \beta_7 TGHG_{t-1} + \varepsilon_{it},$$

where ω represent HICs, LICs, and MICs, TGHG is total greenhouse gas emissions, FFC is fossil fuel consumption, GDPgr is gross domestic product growth rate, FDI is foreign direct investment inflow, MercTrade is merchandise trade, GOC is gas, oil, coal electricity generation, and FertCons is fertilizer consumption.

$$TGHG_{it\omega} = \beta_1 \sum_{i=1}^{\rho} MTF_{t-i} + \beta_2 \sum_{i=1}^{\rho} TGHG_{t-J} + \mu_{1t} \text{ and}$$

$$MTF_{t\omega} = \beta_3 \sum_{i=1}^{\rho} MTF_{t-i} + \beta_4 \sum_{i=1}^{\rho} TGHG_{t-J} + \mu_{1t},$$

where, ω represent HICs, LICs, and MICs, TGHG is total GHG emissions, MTF is monetary transmission framework is disaggregated into broad money (BM), monetary credit to the private sector (MSCPS), world market capitalization (WMKCAP), and world value of traded stock (WVTS).

Estimation Procedure

This paper adopted ARDL, Granger causality test, and impulse rsponse function techniques. Granger causality is used to determine the cause and effect (feedback) between two related variables. The impulse response function seeks to determine the extent to which a percentage change in an independent variable affects the outcome of the dependent variable.

Also, the ARDL is employed to ascertain the short-run and long-run impact in a given functional relationship. ARDL was utilized because of the time-relatedness in climate change trends. Koyck transformation system is utilized to derive the autoregressive distributed lag model (ARDL) environment for the model. However, ARDL was employed because the TGHG effect is either asymmetric or time-bound. The TGHG changes over time contribute to global warming and hence climate change.

RESULTS AND DISCUSSION

Pre-Diagnostic Analysis

Table 1 depicts the hypothesized variables employed in this study. The values are estimated in US ($) dollars. The variables in **Table 1** were selected based on the theoretical underpinning of the nexus between economy (finance) and climate change. These variables in table 1 are proxy variables to capture growth variables (finance-related variables) and climate change indicators. The unit root test result (augmented Dickey-Fuller) is presented in **Table 2**.

The results show that the variables were stationary at first difference. The energy import variable was not utilized because the coefficient of the ADF unit root test showed *1*(2). For a simple illustration, the study showed the trend behavior of HLM for each hypothesized variable. Also, there is the presence of trends for world outlook variables such as market capitalization and the value of traded stock. From **Table 2**, the data set was decomposed into economic activity and finance-related variables.

Table 1. Description of variables

Variables	Acronyms	Source (currency)	Proxy
Total green house gas	TGHG	WDI (US$)	Climate change
Fossil fuel consumption	FFC	WDI (US$)	Transport (distance)
Gross domestic product growth	GDPgr	WDI (US$)	Economic growth
Foreign direct investment inflow	FDI	WDI (US$)	Technology
Merchandise trade	MercTrade	WDI (US$)	Bilateral trade
Gas, oil, and coal electricity production	GOC	WDI (US$)	Manufacturing sector
Fertilizer consumption	FertCons	WDI (US$)	Agriculture sector
Financial system	FS	WDI (US$)	Monetary variable
Broad money	BM	WDI (US$)	Monetary variable
Monetary sector credit to private sector	MCPS	WDI (US$)	Monetary variable
World market capitalization	WMCAP	WDI (US$)	Monetary variable
World value traded stock	WMVTS	WDI (US$)	Monetary variable

Note. Source: Prepared by the authors

Table 2. Augmented Dickey Fuller (ADF) unit root test

Variables	HICs	LICs	MICs	Conclusion
TGHG	-5.797262 (0.0001)	-10.05855 (0.0000)	-6.005148 (0.0001)	*I*(1)
Economic activity variables				
FFC (intercept*) (intercept & trend)	-3.406077* (0.0150)	-6.235634 (0.0000)	-6.662269 (0.0000)	*I*(1)
GDPgr (intercept & trend)	-8.435998 (0.0000)	-7.172342 (0.0000)	-7.821105 (0.0000)	*I*(1)
FDI (intercept & trend)	-7.003961 (0.0000)	-5.192518 (0.0005)	-7.319630 (0.0000)	*I*(1)
MercTrade (intercept & trend)	-7.943067 (0.0000)	-7.312579 (0.0000)	-7.212912 (0.0000)	*I*(1)
GOC (intercept & trend)	-5.403770 (0.0002)	-4.942275 (0.0013)	-6.391523 (0.0000)	*I*(1)
FertCons (intercept & trend)	-4.783796 (0.0043)	-9.740191 (0.0000)	-5.411280 (0.0003)	*I*(1)
Monetary transmission variables				
BM (intercept & trend)	-4.578717 (0.0034)	-8.721531 (0.0000)	-7.730173 (0.0000)	*I*(1)
MSCP (intercept & trend)	-4.897484 (0.0011)	-8.231322 (0.0000)	-7.702442 (0.0000)	*I*(1)
World indicator				
WMKCAP (intercept & trend)		-7.650166 (0.0000)		*I*(1)
WORLDVST (intercept & trend)		-5.216786 (0.0009)		*I*(1)

Note. Source: Eviews 9, *I*(1) first differencing, p-values (), Schwarz info criterion

Table 3. ARDL results

Variables	HICs ARDL(1, 1, 0, 0, 0, 0, 1)	LICs ARDL(1, 0, 1, 1, 1, 0, 1)	MICs ARDL(1, 0, 0, 0, 0, 0, 0)
TGHG(-1)	0.113749 (0.7365)	-0.507976 (0.0109)	0.060897 (0.7083)
FFC	1438259 (0.0281)	64028.69 (0.1132)	15228.91 (0.9736)
GDPgr	-64301.03 (0.5432)	-67957.26 (0.1477)	-135970.2 (0.3020)
FDI	-7.67E-07 (0.0707)	4.13E-05 (0.5531)	4.05E-06 (0.3692)
MercTrade	-63632.18 (0.3580)	-18335.12 (0.5319)	-88902.15 (0.2881)
GOC	206551.3 (0.2198)	-247739.9 (0.0064)	45767.38 (0.7381)
FertCons	-22157.98 (0.3517)	116625.2 (0.2019)	57994.45 (0.2475)
Constant	293356.1 (0.0695)	235971.5 (0.0386)	218729.5 (0.4185)
Bound test	3.478241***	6.882439*	4.284040**
I(0)	2.12	2.96	2.45
I(1)	3.23	4.26	3.61
Cont.Eq.	-0.886251 (0.0225)	-1.507976 (0.0000)	-0.939103 (0.0000)
Long run coefficient			
Constant	331008.032744 (0.1834)	156482.280250 (0.0378)	232913.158257 (0.4102)
FFC	1622857.833463 (0.1716)	107456.294914 (0.0148)	16216.435715 (0.9736)
GDPgr	-72553.984545 (0.5530)	-21653.255869 (0.6644)	-144787.233229 (0.3188)
FDI	0.000000 (0.8937)	0.000027 (0.5531)	0.000004 (0.3583)
MercTrade	-71799.297212 (0.3954)	-12158.762559 (0.5316)	-94667.053385 (0.2957)
GOC	-174178.799064 (0.6918)	-164286.384582 (0.0091)	48735.185063 (0.7390)
FertCons	-25001.92689 (0.4374)	142494.204573 (0.1881)	61755.132371 (0.2510)
LM Test	2.485405 (0.1447)	0.563078 (0.5838)	1.384845 (0.2659)
B-P-Godfrey test	0.918597 (0.5460)	1.074760 (0.4437)	0.544177 (0.7945)
Ramsey test	2.839601 (0.1262)	15.91267 (0.0515)	0.009802 (0.9218)
Normality	0.177668 (0.914998)	0.550751 (0.759287)	0.389634 (0.822985)

Note. Source: Computed by the authors from Eviews, 10%***, 5%**, 1%*, t-statistic (p-values).

ARDL Result Presentation

The bound test result from the ARDL empirically implies that there exists a long-run relationship between GHG emissions and global trade (proxy merchandise trade), technology (proxy by FDI inflow), economic growth (proxy by GDP growth rate), fertilizer consumption, and electricity generation from gas, oil, and coal (GOC). The co-integrating equation showed a negative and statistically significant at 5%.

In **Table 3**, the study paid concerted attention to the process of changes in the explanatory variables from the short run to the long run. The study identified that FFC (fossil fuel consumption), GDP gr, Merch.Trade, and fertilizer consumption showed stable and consistent signs in the long run. This consistency is healthy also for policy manipulation to achieve optimal GHG emissions control. Specifically, the result showed that, in the long run, attainment of global growth (proxy by GDP growth rate) and global trade (proxy by merchandise trade) would de-enable GHGs growth in HICs, LICs, and MICs (HLM). GDP growth and merchandise showed a non-significant negative impact on GHG emissions in HLM. The non-significant negative coefficient of GDP growth rate and Mech.Trade in HLM implies the weakly non-existence of super-wicked problems. Super-wicked problems occur in the climate change and growth nexus because of the complexity and associated positive relationship that higher growth leads to higher GHG emissions that in turn cause climate change. GHG emissions abatement policy reduces the energy mix that limits growth which causes low productivity and low income. The inverse relationship between GDP growth rate, trade, and GHG emissions clearly shows importance of green financing to achieve GPDF for HLM. This result is not consistent with Chien and Sadiq (2022) that found urbanization and economic growth caused more GHG emissions in the long and short run.

Similarly, FFC generated a positive non-significant impact on HICs and MICs and a positive significant impact on LICs on GHGs emissions. FDI inflow's impact on GHGs emissions is positive and statistically non-significantly. The presence of a positive impact of FDI inflow on GHGs emissions in HLM depicts the weak trace of pollution haven hypothesis. The pollution haven hypothesis argued that FDI inflow is detrimental to GHG emission control policy due to the activities of multinational companies (MNCs). This is because the FDI inflow target compromises GHGs emissions reversal, which is consistent with Khan et al. (2020) and Zhou et al. (2018).

Fossil fuel consumption appears with the correct sign. From environment-economic theory, fossil fuel consumption (FFC) builds up GHGs emissions that cause climate change. The result shows that FFC does contribute to global warming. This means that the result is consistent with studies from IPCC, UNFCCC, UNEP, and WMO. The result obtained from ARDL shows that in the long-run, FFC impact on GHGs emissions is significant in LICs and non-significant in HICs and MICs. This result connotes that aggressive attention is channeled on the FFC exploration in the LICs. Interestingly, electricity is an important input in production. The use of Gas, Oil, and Coal (GOC) as an energy mix to boost electricity (transportation system) is equally significant to achieving the growth target. In **Table 3**, the impact of GOC on GHGs emissions is non-significantly negative in HICs and LICs and non-significantly positive in MICs. This result connotes that MICs have high GOC intensity. This implies that MICs substantially explore GOC for electricity more than HICs and LICs. Green technology financing on MICs would be optimal to reverse GHGs emissions. The significance of this result going forward could imply two extreme scenarios is amenable to the intent that HICs (GOC-less economy) and MICs (GOC-exploration economy). In the long run, the prevailing scenarios could be interpreted as the reason for the enabling role of GOC in MICs. Fertilizer consumption (FertCons) is employed to proxy the impact of agricultural production on GHGs emissions. The result showed that FertCons in MICs and LICs positively exacerbate GHGs emissions and FertCons in HICs reduce GHGs emissions. This differential impact of FertCons could be owing to the less dependency of HICs on primary production but service. The large dependency on the agricultural sector in LICs and MICs explains the reason for the overarching impact of FertCons on GHGs emissions. The impact of FertCons is not a significant contributor to GHGs emissions. Thus, rethinking the growth-climate change nexus, it is obvious that the negative coefficient of GDP growth impact on GHGs in HLM meets the last phase of the Environment Kuznets Curve (EKC). In terms of policy prescription, the negative relationship between GHGs emissions and GDP growth rate (a proxy for per capita GDP) connotes that post-COVID 19 growth targets could be achieved under a net-zero emission target or low-carbon emission. Therefore, the result signifies the exigency to leverage green financing to deepen the decoupling agenda. It is imperative to posit that the global poverty level in sub-Saharan Africa might threaten the inverse relationship between GDP growth and GHGs emissions. For LICs and MICs in the long run, the non-significant coefficient of the impact of GDP gr on GHGs emissions implies that sustainable policy on the social cost of greenhouse emission (SCGE) should be leveraged to correct the negative externality that could be generated in the FFC, FDI inflow, FertCons, and GOC which appear with a disturbing impact on GHGs emissions trend in LICs and MICs. Evidence in the literature portrays the issue of non-inclusiveness in the GDP growth rate. This rationalizes the exigency for energy intensity. With the impact of FFC, FDI inflow, etc., the decoupling target might be compromised

Three priority areas where the green central banking perspective could effectively stimulate the decoupling debate are through the FDI inflow (a proxy for technology), growth rate, and trade. This is because of the portent role finance channels generate in influencing the outcome of the foregoing explanatory variables in the long run. FDI inflow enables GHGs emissions in the long run in HLM. The result supports the green financing mix to stimulate technology adaptation, deployment, and installation, to reverse the positive impact FDI inflow, has on GHGs emissions. Schumpeter's creative destruction policy is practically apt to accelerate green financing that would generate green FDI inflow to de-enable GHGs emissions in HLM in a sustainable dimension. The positive impact of FDI inflow on GHGs emissions is practically infinitesimal. The result shows that greener FDI inflow and sustainable central bank policy to incentivize green capital inflow (green bond) to help countries acquire and install new technologies should be prioritized. The pollution haven hypothesis squares well to align the call for green technology through monetary transmission mix as noted in Lagarde's (2021) declaration on green central banking to attain GHGs emissions control policy that helps the global economy.

Pairwise Result Analyses

This study utilized the pairwise granger causality technique. This technique is utilized to examine the cause and effect between broad money and GHGs emissions, monetary credit to the private sector and GHGs emissions, world value of traded stock, world market capitalization, and GHGs emissions. The lag length for various analyses was determined. The lag length criteria were utilized to determine the appropriate lag structure for the analyses. It is pertinent to recall that finance variables channels affect real sector outcomes through monetary variables (Taylor, 1995). This study proxy finance-related variables with broad money, monetary credit to the private sector, world value of the traded stock, and world market capitalization. This paper examined the overarching importance of GHGs shock on key macroeconomic variables such as FDI inflows, trade, and GDP gr through finance-related variables channels. Hence, the causality result results are presented in the appendix. The causality between broad money and TGHGs emissions (total GHG) in HICs is 38.1% and 30%. In LICs, the causality between broad money and TGHGs emissions are 31% and 84%. For MICs, the cause-and-effect coefficient between broad money and TGHGs emissions is 29% and 80.4%. These coefficients captured the representative p-values of the hypothesized variables. The p-values are higher than 5%. Hence, the results do not support causality between broad money and TGHGs emissions across the regions. This study investigated the cause and effect between GHGs emissions and monetary credit to the

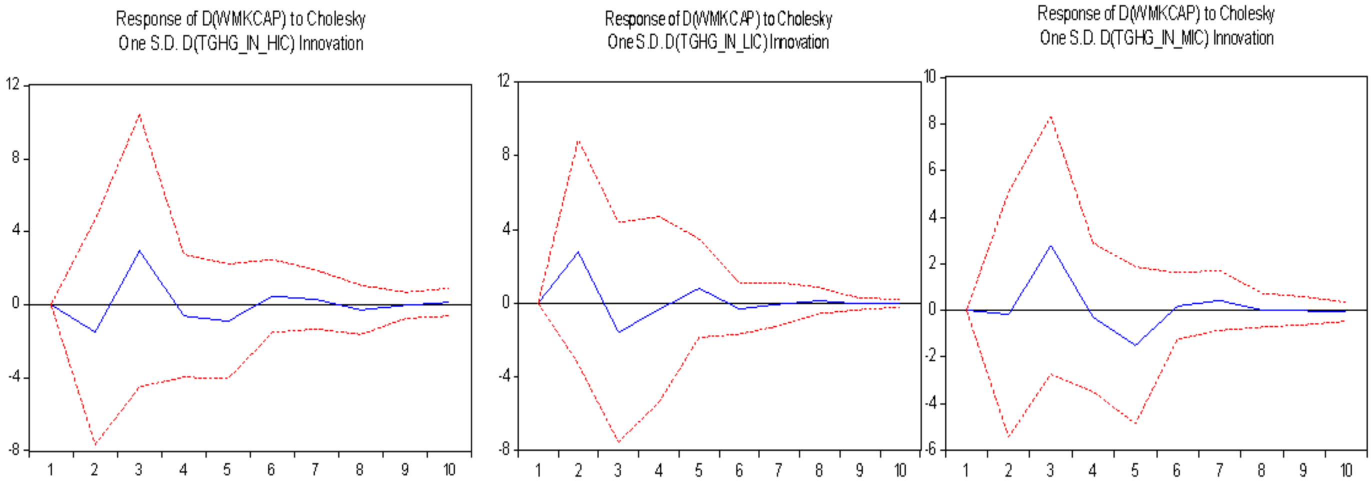

Figure 1. World market capitalization and GHG in HLM

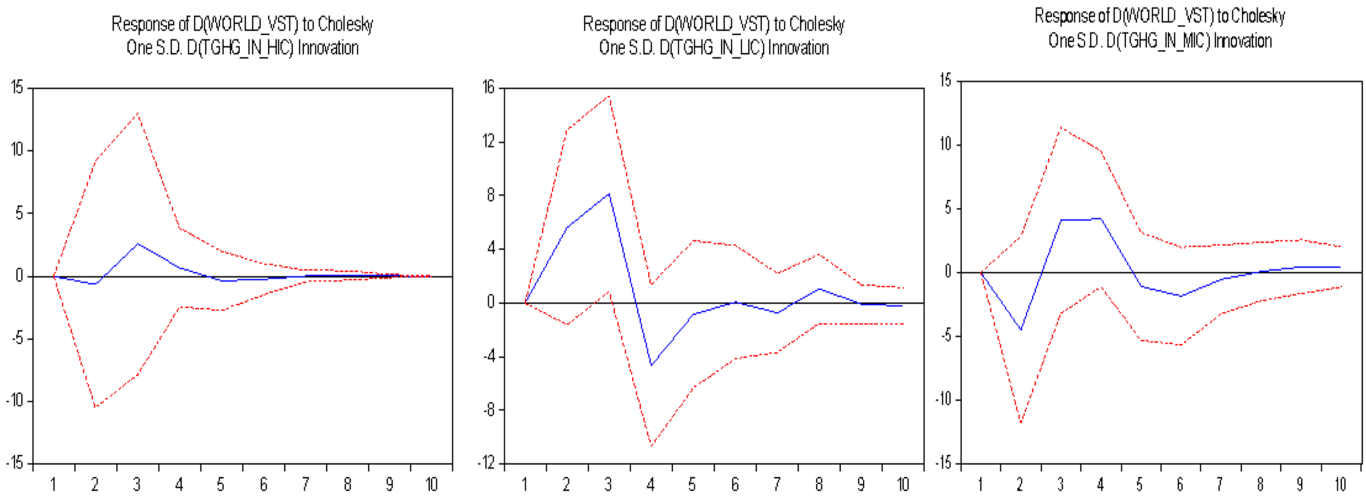

Figure 2. World value of traded stock and GHG in HLM

private sector (MCSP) in HLM. The causality between MCSP and TGHG emission in LICs, MICs, and HICs are 10.3% and 75%; 45.8% and 21%; and 92.7% and 98.7%, respectively. These corresponding p-values are higher than 5%.

The results found no causality between GHG and world market capitalization (WMKCAP) and GHGs and world value of traded stocks (World_VST). Hence, we, therefore, accept the null hypothesis. Based on the non-existence of causality between GHG emissions and finance-related variables. This study finds that TGHGs emissions in LICs and MICs are causally related at 5%. The corresponding p-values are 0.01% and 0.017%. The result implies that the GHG emissions in MICs and LICs have tendencies to worsen the global GHG emissions and concentration. The study employed IFF to determine how finance-related variables respond to GHG emissions shocks. IRF rationalizes the non-causality based on the p-values coefficient.

The results from pairwise test could not trace cause and effect between finance-related variables and GHG emissions. The result shows that there is no causality between the monetary transmission variable and GHG emissions in HLM. Hence monetary variables do not granger cause GHG emissions and vice versa. The result is not consistent with finance-climate change studies that have *apriori* shown loan risk and default caused by finance shock and volatility as GHG emissions worsen over time. However, based on the reality of the susceptibility of loan risk and implosive shock caused by GHG emissions (climate change). The study found the presence of volatility and monetary transmission is fundamentally susceptible to GHG shock.

Impulse Response Function Analyses

The results showed that world market capitalization (**Figure 1**) and world trade stock (**Figure 2**) showed volatility responses to one percentage standard deviation shock emanating from GHGs emissions. The study employed shock response to investigate the effect of GHGs emissions on the economy through the finance-related variables e.g., world market capitalization and world trade stock.

Figure 3 captured how monetary credit to the private sector responds to shocks to a percent change in GHGs emissions. To simplify the illustration, this analysis decomposes the shocks to offer a regional outlook represented as HLM. The volatility for HICs is less compared to LICs and MICs that produced massive volatility response in a monetary credit to the private sector as GHGs emissions are forecasted in a ten-year period.

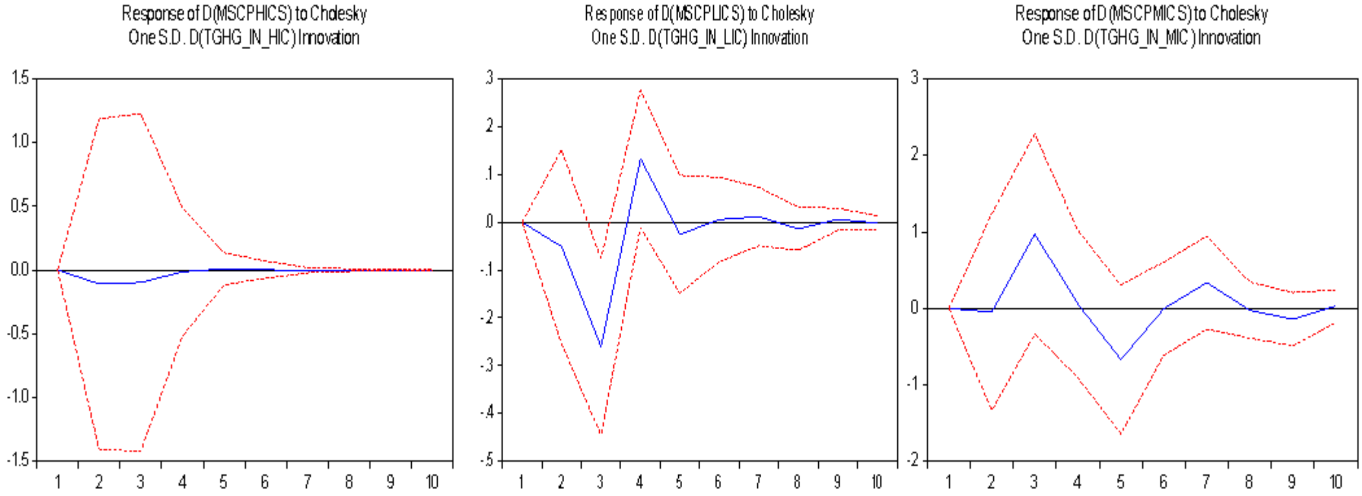

Figure 3. Monetary credit to the private sector and GHG emission in HLM

CONCLUSION AND RECOMMENDATIONS

Based on the results, this paper concludes that there is a long-run relationship between selected economic indicators and GHG emissions in the global economy. In the long run, the GHG emissions enablers are FDI inflow and fossil fuel consumption. On the other hand, de-enablers of GHG emissions are GDP growth rate and merchandise trade. However, GOC and fertilizer consumption have mixed finding across the regions. Also, the study observed that there exists no causality between GHG emissions and selected finance-related variables. A 1% shock in GHG emissions generates monetary volatility. Based on the findings that global trade generates a similar impact on GHG emissions across HICs, LICs, and MICs.

Economists have long debated a carbon emission tax and cap-and-trade policies to attain a climate decoupling target in response to the policy-planning problems associate with carbon emission abatement and control. Policy orientation on global growth targets has complicated global responses on mitigation and adaptation hence the imposition of tax on enablers of GHGs emissions. Regrettable policy debate on decoupling or recoupling through a deliberate carbon emission tax regime for the global economy seems inconclusive. Largely due to the variant policy approaches canvassed to achieve robust and inclusive growth, energy use mix, as well as climate stability. Therefore, integrating the SCGE e.g., carbon tax and cap-and-trade on enablers of GHGs emissions exported by emitters countries. At the same measure compensate the importing countries (non-emitters countries) by adjusting the price-exchange differential needed to import commodities that are enablers of GHG. Presently, the carbon tax imposition on carbon emission are lopsided, but should be implemented without disrupting global trade.

In the long run, integrating SCGE on bilateral (net export) trade of commodities that enable GHGs would enable the global commitment and preference for a green technology as well as improve the energy-financing mix that incentivizes decoupling and accelerate global trade competitiveness through appropriate green financing instruments with sustainable low-carbon solution. Integrating efficient social cost would drive the campaign on climate change reversal to achieve global carbon emission abatement and control policy and net-zero emission target by 2050. This paper determined the enablers and de-enablers of GHGs. Industrialized nations heavily account for the climate change progression, poor nations are at the receiving end of the climate change dilemma due to the region's weak infrastructure in adapting and mitigating the impacts of climate change. The imperative for imposing the SCGE on regional enablers is to guarantee an equilibrium frontier on the climate change reversal agenda. Due to the escalating global mean temperature and its associated risk and uncertainty, the SCGE on factors that enable climate change has been overwhelmingly expedient.

Specifically, this study concludes the followings:

1. **H1:** GDP growth rate and GHGs emissions have a decreasing long-run functional relationship. This study accepts the null hypothesis.
2. **H2:** Merchandise trade is negatively related to GHGs emissions. This study accepts the null hypothesis.
3. **H3:** FDI inflow has a long-run positive impact on GHGs emissions. This study accepts the null hypothesis. This result is consistent with the pollution-haven hypothesis.
4. **H4:** Fossil fuel consumption positively affects GHGs emissions. The study accepts the null hypothesis.
5. **H5:** Electricity generation from GOC negatively impact on GHGs emissions in HICs and LICs. However, in MICs, GOC increases GHG emissions.
6. **H6:** The higher the fertilizer consumption, the lower the GHGs emissions in HICs. But fertilizer consumption in LICs and MICs exacerbates GHGs emissions. This study accepts the null hypothesis.
7. **H7:** There is no relationship between the monetary transmission framework and GHGs emissions. Thus, we accept the null hypothesis.
8. **H8:** We accept the alternative hypothesis that monetary transmission responds to GHGs emissions shock in HLM.

The study utilized the p-values in ARDL in **Table 3** to compute the significance of the hypotheses for the study. The underlying philosophy underpinning the determination of enablers and de-enablers of GHGs emissions is to provide a robust implementation of SCGE. Thus, the study recommends that an efficient SCGE tax policy should be integrated through forward and backward finance-related. This process would set a signal that guarantees the development of robust green central banking financial instruments, which in turn, accelerate green growth as well as achieve sustainable climate change reversal, and set the pace for an industrial green tech revolution. Finance-related channels would drive a market-based framework rather than the hitherto arbitrary integration of SCGE. Finance-related channels would incentivize competition and enable the formulation of green financing instruments to help mitigation and adaptation processes.

This study supports the pollution haven hypothesis. It implies that exogenous technology does not guarantee environmental quality in the recipient economy. Hence, green financing that ensures the adoption, installation, and diffusion of an environment friendly-technology would square well to achieve decoupling. Aside, from FDI worsening climate change, global trade from evidence contributes to GHGs emissions. An application of the SCGE tax on bilateral trade would be far-reaching in reducing emissions in the global economy. This study recommends that every country's carbon cost should be determined by the monetary transmission channels governing economic interaction in each country. The underlying philosophy is that the SCGE tax should leverage finance-related channels to stimulate macroeconomic indicators rather than stifle them.

Green central bank perspective in collaboration with WMO, intergovernmental panel on climate change (IPCC), and WTO (2020c) should ensure that the carbon emission tax payment system reflects the appropriate GHGs emissions cost generated in each country. The tax is therefore deducted through SCGE from emitters to the recipient economy. This process would accommodate negative externality hitherto neglected in bilateral trade. Griffiths et al. (2020) argued that SCGE is based on the monetary value ($50) of one tone of CO_2 emitted into the atmosphere. This study argues that arbitrary imposition of emissions cost could be non-inclusive and inequitable. SCGE should follow a channel that accommodates the cost it causes in damaging the biodiversity and ecosystem by adjusting the global trade and supply chain from emission-generating countries' (EGC) balance of payment system. The implication becomes countries with high GHG emission rates would undertake the financial cost of engaging in high GHG emission trade through global trade emission and environment support taxes (GTEST) e.g., carbon taxes and carbon prices in favor of low emission countries. GTEST in the long run could prevent reciprocal dumping, promote competition, and sets new green technology financing frontiers.

So, therefore, the cost of the GHGs emissions (proxy by SCGE) should be implemented through monetary transmission channels based on the evidence offered through the enablers and de-enablers of global GHGs emissions. In a simple template, economic activity should be adjusted through

1. sectoral emission and supply chain of countries (production of exported goods and services) by the extent to which the activity enables GHGs emissions and
2. adjustment should be implemented by way of introducing direct taxed on the primary and semi-finished inputs that enable GHGs emissions value used by sectors in importing countries.

Thus, exported, semi-finished imported, and consumer goods could be appropriately adjusted value-added tax (VAT) that goes to support the design, deployment, and installation of renewable and green technology to expand the frontier of global adaption and mitigation. The logic underpinning the application of SCGE on the enablers of global GHGs emissions is to support global response to achieving optimal GHGs emissions control and energy efficiency policy target 2050 called net zero-emission.

Limitation of the Study

Time series data utilized in this paper were inadequate. Also, the regional decompositions of data for finance-related variables were not found. Hence, the paper could not determine the impact of GHGs emissions on finance-related variables for specific regions. This area should be appropriately investigated to deepen regional environment-economy debate and the discourse on cap-and-trade.

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