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Research Article

Climate Change Scare and FDI Migration

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ABSTRACT

Does foreign direct investment (FDI) migration into Nigeria and Sierra Leone generate a climate change scare (CCS) based on the pollution haven-halo hypothesis? The quasi-experimental design study utilized data from the world development indicator, 1970-2019 using a nonlinear autoregressive distributed lag (NARDL) model to estimate the dynamic impact of FDI migration on CO_2 emissions (a proxy for CCS). The study found that the change in FDI migration in Sierra Leone causes upward CO_2 emissions. The positive impact of FDI migration on CO_2 emission implies that the pollution haven hypothesis exists in Sierra Leone. Comparatively, dynamic FDI migration into Nigeria caused a mixed impact on CO_2 emissions. The result found that an increase in FDI migration caused a decrease in CO_2 emissions in Nigeria. Similarly, a decrease in FDI migration caused an increase in CO_2 emissions. Also, the Wald F-test suggests a long-run asymmetry and symmetry between FDI and CO_2 emissions in Sierra Leone and Nigeria, respectively. Hence, there is the presence of a pollution halo-haven issue in Nigeria. The study, therefore, recommends that green FDI financing that supports environment-friendly technology export into Nigeria and Sierra Leone that would enable optimal climate change control both in the short- and long-term. Thus, technology that efficiently improves environmental quality, preserves, and protects the ecosystem should be imported into Sierra Leone and Nigeria.

Keywords: FDI migration, climate change scare, pollution haven-halo hypotheses

INTRODUCTION

There is an absence of consensus in the literature on the extent to which multinational companies (MNC) export or transfer greenhouse gases globally. MNC pursues profit objective over environmental objective in their foreign direct investment (FDI) migration (foreign capital penetration). In the recent past, developing countries have shown high interest in response to FDI migration. Consequently, developing countries have become less restrictive in its foreign investment policy to deepen the character and magnitude of FDI (foreign capital penetration) migration, in order to bridge the investment and saving gap (Chenery & Strout, 1966). However, the resource-seeking behavior of multinational enterprises (MNEs) and foreign investors in developing countries has resurrected concern about the FDI-environmental damage nexus.

Baek (2016) and Seker et al. (2015) posit that FDI has a dampening impact on the environment. Asghari (2013) observed a weak and statistically significant relationship between FDI and CO_2 emissions. But, according to Kim and Baek (2011), FDI produced favorable incentives for environmental renewal in developing and developed countries. Hence, the activities of MNC's FDI migration in developing countries have recently come under intense scrutiny.

The trend of environmental disruption in the developing countries, due to the emergence of loss of diversity, deforestation, and rising greenhouse gas emissions (GHGs) as well as the issue of an irreversibility of the potential environmental damages and threats to the ecosystem begs the question of the environmental impact of FDI on sustainability goal. The issue of climate change becomes topical due to rising global mean temperature beyond the 1.5°C target. The associated weather pattern such as high rainfall and flooding, and unpredictable weather patterns have become a normal occurrence that makes life vulnerable, affect the agricultural lifecycle, and leads to uncertainty in the financial outcome (loans and advances) which present long-run development challenges for developing countries.

Recent studies are overwhelmingly concerned about the feedback effect of the physical risks associated with the climate change scare (CCS). Literature on the CCS is purely anchored on the shock and risk effect, and the uncertainty as well as the long-run damaging effect on the economy. Developing countries become susceptible to issues of divergence of the absence of appropriate buffers to withstand the pressure from the unpredictable change in the atmospheric behavior. The crux underpinning the debate is whether FDI migration via MNE operations and technology channels, creates pollution that causes CCS in the recipient (host) developing countries? Specifically, does FDI migration cause CCS in Nigeria and Sierra Leone? Which of the hypothesis best explains the nexus between FDI migration and climate change? The objective of this study is to determine whether a dynamic pattern in FDI migration leads to CCS in Nigeria and Sierra Leone. FDI-technology migration into the fossil-fuel dependent sectors e.g. mining, oil and gas exploration, reveals the issue of the environmental impact of FDI on the development. Economists have questioned the empirical suitability of FDI migration to boost the environment (decoupling) as well as stimulate growth in developing countries through technological channels (Brunnermeier and Levinson, 2004; Kellenberg, 2009; Sauvant and Mann, 2017).

This study is divided into five major parts: introduction, literature review, methodology, results and discussion, and conclusion and policy recommendations.

LITERATURE REVIEW

FDI is classified based on the direction of flow, nature of production process, motive, and sectoral dimension (Patterson et al., 2004). The imperative of FDI on the global economy is mixed. For instance, McKinnon (1973) and Shaw (1973) support financial liberalization, and Moyo and Le Roux (2020) support capital globalization. Conversely, issues such as contagion and liquidity effect (Claessens and Forbes, 2001; Detragiache and Spilimbergo, 2001; Kaminisky et al., 2003; Reinhart et al., 2002), volatility effect (Calvo and Reinhart, 2000; Mody and Taylor, 2013; Rodrik and Velasco, 2000), procyclicality effect (Calvo and Reinhart, 1999; Kose et al., 2003; World Bank, 2001), financial crisis (Dymski, 2005), etc. presents capital globalization (sub-species of FDI) as distortive to growth. Based on the foregoing ambiguity leveraging on FDI migration becomes a situational and country-specific issue.

Scholars are vexed with the fact that FDI migration stimulates new technology (Stefanovic, 2008), increases the spillover effect (Blomström and Kokko, 2000; Borensztein et al., 1998; Sjöholm, 1999; UNCTAD, 2000), accelerate technology transfer linkages for firms (Grossman and Helpman, 1991; Lim, 2001; Smarzynska Javorcik, 2004), stimulate innovation (Caves, 1996), enables competition (Blomström and Kokko, 1998; Lee and Tcha, 2004; Pessoa, 2007), fast-track multiplier firm's investment effect (de Mello Jr., 1997), boost integration (Barry, 2000; Zhang, 2001, 2006), improve financial sector development (Caprio and Honohan, 1999; Levine, 1996), and drive R&D across borders (Blomström and Kokko, 1998; Hanson, 2001). FDI enables the deliverables of infrastructures that reduce operating costs and boost investment (Henry, 2000; Stulz, 1999; Wheeler and Mody, 1992). Ariyo (1998) opines that FDI stimulates development in sub-Saharan Africa. In Africa, the new partnership for Africa's development (NEPAD) policies to attract FDI remains a core investment for growth (Stefanovic, 2008). Policies to attract FDI is dependent on factors as demonstrated in Murthy and Gambhir (2017) trade (investment)-environment triangle model which is consistent with Lall and Streeten (1977) argument. The core drivers to attract FDI include infrastructure (Wheeler and Mody, 1992), the exchange rate (Calderon-Rossel, 1985), political indices (Edwards, 1990), trade openness (Balasubramanyam et al., 1999), and absorptive capacity (Aitken and Harrison, 1999; Alfaro et al., 2004; Arteta et al., 2001; Bailliu, 2000; World Bank, 2001, 2021).

Theoretical Literature

The literature recognizes two channels through which FDI migration impact on the environment of the host countries. These channels, therefore, give rise to viz; pollution haven hypothesis: polluting industries will shift to locations with environmental lax standard and regulation (Kathuria, 2018), pollution halo hypothesis (clean technology argument), and scale effect hypothesis (growth expansion cause emission which adversely environmental degradation positively (Alvarez-Herranz et al., 2017). Also, the income levels and environment pollution relationship, which is conceptualized as environmental Kuznets curve (EKC) is relevant to the theoretical underpinning relationship between FDI and the environment (Copeland and Taylor, 2004; Dasgupta et al. 2002; Dinda, 2004). Porter's (1991) hypothesis is utilized as a policy response to the issue of environmental degradation. Porter's (1991) hypothesis argued that stringent environmental regulation is beneficial for polluting firms and through feedback such policies could stimulate innovation which in turn increases the productivity of firms. The beneficial (halo hypothesis) and harmful (haven hypothesis) underpin dimensions of FDI migration on climate vulnerabilities in developing countries.

Empirical Literature

Polloni-Silva et al. (2021) opined that a stable non-linear relationship between gross domestic product (GDP) per capita and CO_2 emissions and the halo hypothesis exists in Sao Paulo. Singhania and Saini (2021) found that FDI has a positive significant impact on environmental degradation. The system-generalized methods of moments show evidence of the pollution haven hypothesis. Sarkodie and Leirvik (2020) using dynamic heterogeneous estimation technique support pollution haven hypotheses in Africa. The study holds that renewable energy intensity reduces CCS in sub-Saharan Africa (SSA), and income level worsens pollution which affects climate change. Barua, Colombage, and Valenzuela (2020) autoregressive distributive lag (ARDL) study finds 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 (2014) posit that remittances into Brazil, Russia, India, China, and South Africa are the source of environmental degradation. However, in India, remittance reduced climate-CO_2 emissions. The study revealed that FDI inflow increases CO_2 which aligns with the pollution haven hypothesis. Li et al.'s (2019) FDI has an insignificant influence on environmental performance for a panel study between 1990 and 2014. Murthy and Gambhir's (2018) cubic model validates the pollution haven hypothesis in India for a model that integrates EKC and pollution halo-haven (PHH). Zhou et al. (2018) found that FDI increases carbon emissions in China.

Similarly, Zhu et al. (2016) obtained that the FDI effect on climate change is negative in countries with medium and high carbon emissions. Vinh (2015) found that FDI causes a rise in pollution-GHG emissions. The result supports the pollution haven hypothesis for Vietnam. Atici (2012) showed that FDI is favorable to Asian countries because there exists an inverse (decreasing) functional relationship linking FDI and climate change. Doytch and Uctum (2011) adopted pooled OLS estimation and found that FDI inflow into the manufacturing sector and poor countries support the pollution haven hypothesis, FDI inflow into the service sector and rich support the halo effect hypothesis. Deng and De-yong (2008) used panel data analysis and Liang (2005) employed the time series model and panel data found that FDI improves environmental quality and alleviates carbon emissions respectively. Grimes and Kentor (2003) adopted a cross-national panel regression analysis of sixty-six less developed countries. The study found that foreign capital penetration between 1980 and 1996 has a significant positive impact on growth in CO_2 emissions.

Some Stylized Facts on Climate Change and FDI Nexus

The term Climate Change Scare (CCS) is conceptualized to raise global awareness of the implosive tragedy that dynamic weather patterns for the ecosystem. Presently, the measurement of CCS is still subjective in the literature. Due to the adverse phenomenon of climate change, the term scare becomes inevitable. To remedy the climate change phenomena, the global focus is concisely placed on the optimal instruments to reverse the CCS to achieve decoupling and recoupling. The CCS is decomposed into physical risk and transitory risk. These risks generate permanent and temporary shocks in the economy. Scholars opined that the CCS is dynamic and produce shocks that influence the demand-side and supply-side of the economic relationship. Over time Scholars are worried about the dynamic nature and dimension of risk that climate change shock generates on the economy. Climate change causes output volatility (Cavallo and Noy, 2010), disrupts agricultural productivity (Cuervo and Gandhi, 1998), causes labour supply disequilibrium (Fankhauser and Tol, 2005), leads to capital depreciation (Stern, 2013), brings about insurance losses (Bank of England, 2015).

CCSs demand short-term direct regulation. Keynes (1936) admits that in the long run, we are all dead. If climate change continues unabated ceteris paribus, the long-run cost would sufficiently suppress the natural conditions of the ecosystem which will expose existence to an unimaginable risk. The climate change issue has attracted stimulating policy discussion about the unpredictable impact its long-run threat portends. Studies on the changing pattern of the biodiversity and ecosystem are closely monitored by the World Meteorological Organization; Intergovernmental Panel on Climate Change, NASA, UNEP, United Nations Framework Convention on Climate Change, and other global environment agencies show relatively global warming beyond the 1.5°C COP 21 target. With the net-zero emission target by 2050, can the global community achieve the less than 1.5°C COP 21 target?

Emerging evidence on the dynamical (statistical) properties of climate change shows that the environment is in crisis (HDR, 2019). Changing statistical properties in **Figure 1** shows that global temperature, sea level, and CO_2 emissions

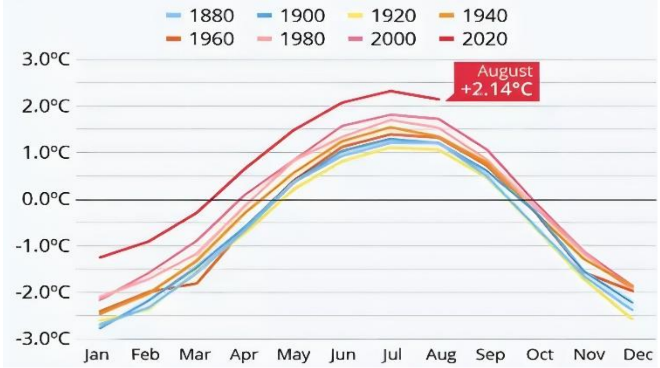

Figure 1. Global earth temperature (1880-2020)
Source: Adapted from NASA (2020)

Figure 2. 2020 Earth's Reality and Global Warming
Source: NASA

increased to 2.1°F since 1880, 3.3 million per year (mpy), and 416 part per million (ppm) respectively. On the other hand, arctic ice minimum and ice sheets dropped to 13.1% per decade and 429 billion metric tons per year (NASA, 2020). There are eight periods from 1880 to 2020 illustrated in **Figure 1**.

According to NASA (2020), these changes represented in different periods depict global warming. These periods constitute a significant threat to the weather events in terms of strength, frequency, spatial extent, and duration. Due to the changes in the global earth temperature which is shown to be heating up to +2.14°C in 2020 hotter than the average month recorded on earth in 1880. NASA (2020) going forward predicts that the earth reality in **Figure 2** is the most likely due to the emerging global earth temperature.

Given the new normal on the climate vulnerability, UNESCO's climate vulnerability index (CVI) in **Figure 3** provides a geographical outlook of countries' threat levels decomposed into a high, medium-high, medium, medium-low, and low country climate-vulnerable index. Africa's CVI is unarguably in crisis. This implies that Africa has a high climate vulnerability that leads to CCS. CCS generates risks and uncertainties which creates hazards and toxics on the economy. The risk and uncertainty generated by CCS affect economic interactions due to the direct nexus and interdependencies between the environment and economy. In the deepest form, scholars agree that environmental crises are caused by the degree of rising temperature, flooding, sea level, droughts, weather events, etc. In the literature, the concern over time has been to measure the exposure and manifestation of shock, the CCS generates on the financial and economic channels that underpin macroeconomic behaviors (Bruno &

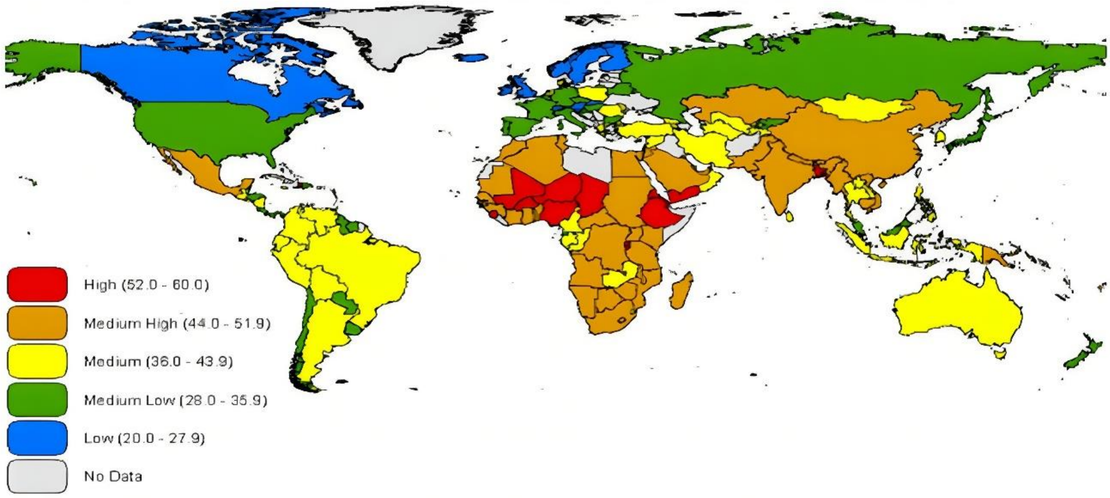

Figure 3. UNESCO CVI
Source: Adapted from Sullivan et al. (2009)

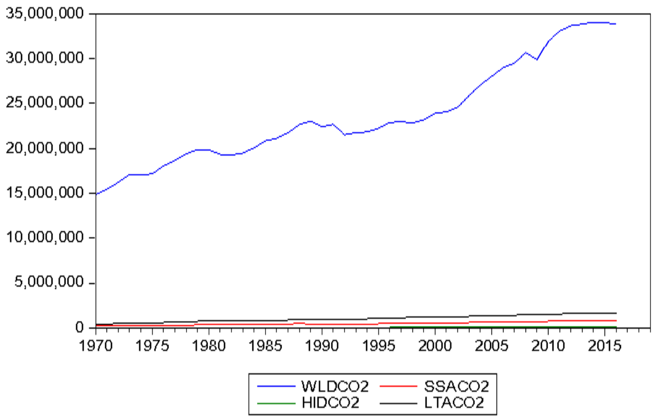

Figure 4. World and the selected regional CO_2 emissions

Shin, 2015). However, the unpredictable behavior of weather events as well as the dynamic nature of the ecosystem has made CCS topical because of the inevitable role the environment plays in human existence.

Buttressing Sullivan's (n. d.) thought in **Figure 3**, Nigeria and the majority of African countries have high and medium-high CVI. From the diagram, the CVI in Africa is unfortunately overwhelming. The long-run implication of CVI portends that Africa has a high-risk environment. Based on this staggering insight in **Figure 3**, economists have unanimously agreed on the nature and risk and uncertainty climate shock has on economic activities vice versa. There is consensus on the relative susceptible and intrinsic exposure risk that climate change shock produces on the economy. Scholars have opined that poverty and inequalities stifle the mitigation and adaptation process in climate change control. In the process of adopting strategies to overcome poverty through attracting FDI inflow to stimulate domestic production, the environment is arguably threatened.

In **Figure 4**, there is a wide departure between world CO_2 and Latin America CO_2 ($LTACO_2$), sub-Saharan CO_2 ($SSACO_2$), high indebted poor countries CO_2 ($HIDCO_2$). The trends show increasing global CO_2 levels, but the CO_2 pace of selected countries seems quite unclear. When juxtaposed with **Figure 3**, where countries such as Nigeria, Ethiopia, Chad, and Sudan tend to have high CVI.

Battern (2018) opined that transitory risk is caused by policy redirection towards a low-carbon economy. Closely linked to the transitory risk are the issues of attaining SDGs and inclusiveness. The paradox is that based on the degree of openness and interdependencies, carbon emission control policy to mitigate CCS, affects energy use, which in turn increases climate change shock on the economy. Bauer and Rudebusch (2020) proposed a social discount rate (SDR) policy to achieve decoupling. SDR is anchored on the cost and benefit literature because of the emerging realization of the time dimension and the implication of the inevitable anthropogenic (human-influenced economic activities) and the unpredictable exposure climate vulnerabilities generate over time.

FDI Migration into the Developing Economy

Global (exogenous) capital migration is decomposed into the pull and push components (Calvo et al., 1993). The impact of exogenous capital migration on EG can be traced through several channels namely direct channels (transfer of technology) and indirect channels (specialization). Reisen and Soto (2001) contend that FDI can be helpful in terms of accelerating recipient countries' EG. Evidence exists on the various dimension of FDI on growth. The elaborate impact of FDI on the developing economy is traceable to studies such as Acadie (2009), Agosin and Machado (2005), Akinlo (2004), Amaefule (2019), Amaefule and Shoaga (2019), Amaefule et al. (2019), Bello and Adeniyi (2010), de Mello Jr. (1999), Ekpo (1997), Fedderke and Romm (2006), Gyapong and Karikari (1999), Irandoust and Ericsson (2005), Khan (2014), Lensink and Morrissey (2001), Schneider and Frey (1985), Tintin (2012), and Umoh et al. (2012). These foregoing studies notwithstanding the impact of FDI on developing countries showed mixed findings. Critically, these studies could not accommodate the recent emerging policy discussion on the impact of FDI on CCS through its role on growth through technological channels.

The trend of FDI migration in low-income countries (LICs) portrays three phases. These phases emanating from the trends show low FDI migration, high FDI migration, and decreasing FDI migration. Factors not limited to the economic environment, political stability, infrastructure, exchange rate,

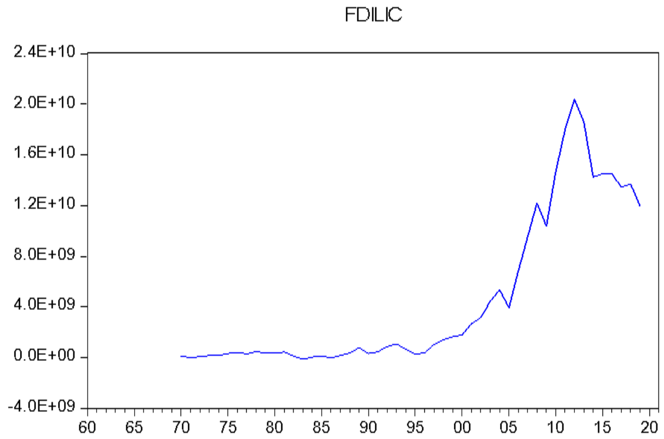

Figure 5. FDI inflow in LICs (1970-2019)

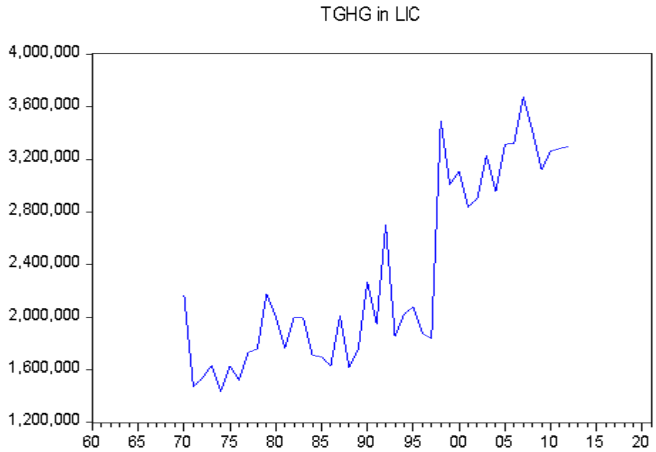

Figure 6. GHG emission in LICs

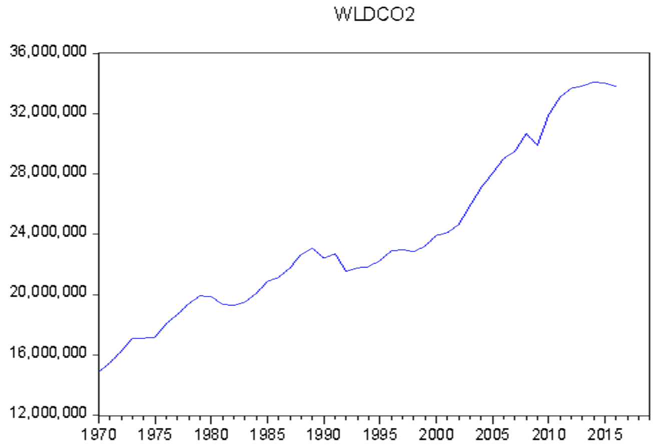

Figure 7. World CO_2

etc. are core determinants that may likely influence the behavior of FDI migration into developing countries (proxy by FDI migration into LICs).

Evidence from FDI migration in **Figure 5** underpins the various interpretation held by scholars. Given the staggering trend, economists thereby wonder about the probable consequence of FDI migration in the CCS debate.

DATA AND METHODOLOGY

This paper employed a quasi-experimental design. The task in this article is to deeply reconcile the paradox between the desirable nature of FDI migration and the undesirable nature of climate change (pollution). In the literature, Solow (1956) robustly argued that exogenous technological migration is a sine qua non for growth. The exogenous growth function (EGF) argued that growth is generated from inputs such as technological progress, rates of savings, depreciation, and population growth. The logic underpinning the EGF theory is premised on the constant return to scale (CRS), continuous, and substitutable nature of EGF. The CRS dimension of EGF connotes that doubling technology leads to doubling growth.

Data

Data were sourced from world development indicators. Asiedu (2002) leveraged FDI migration as an explanatory variable to explain CCS. This paper approached this nexus from a quasi-experimental design enabled in a nonlinear autoregressive distributed lag (NARDL) model. NARDL permits the estimation of short-run and long-run nonlinearities through the positive and negative partial sum decomposition of the FDI migration (Shin et al., 2014). NARDL is structured in the process in the bound testing without considering the order of integration either $I(0)$ or $I(1)$ but $I(2)$. It involves the determination of asymmetric dynamic multipliers, the application of Monte Carlo simulations to evaluate the properties of the parameters, and the estimated results.

Theoretical Framework

Trends in CO_2 emissions (**Figure 6**) and FDI migration (**Figure 7**) could be modelled in an asymmetric function. The obvious fact is that FDI inflow and CCS are predicated on the dynamic changes. The dynamic dimension of FDI inflow and CCS could be tailored through the PHH hypotheses (PHH-H). These hypotheses argued that CCS responds to the dynamic changes in FDI inflows. PHH-H put forward a controversial template on the impact of FDI inflow on CCS through technological channels. The pollution halo hypothesis finds FDI inflows as a conduit for abating carbon emission. On the other hand, the pollution haven hypothesis supports FDI inflows as an instrument for gross carbon emission problems in the recipient country.

Ehrlich and Holdren (1971) developed a climate impact model developed as a function of population, affluence, and technology called the IPAT model. Over time due to the criticism in IPAT. Dietz and Rosa (1997) reformulated IPAT into stochastic impacts by regression on population, affluence, and technology (STIRPAT). The STIRPAT recognizes the cycles of causation between human systems and the ecosystem upon which they depend. STIRPAT provides the theoretical model used in explaining the pollution haven hypothesis, and pollution halo hypothesis. Given the Wang et al. (2017) STIRPAT in asymmetric laplace distribution mixture model. This study modified Wang et al. (2017). Given as,

$$STIRPAT\,I_t = \alpha P_t^{\beta} * A_t^{\gamma} * T_t^{\delta} \varepsilon_t, \quad (1)$$

where α is the constant term, $\beta, \gamma,$ and δ represents parameters, and ε_t is the disturbance term. Based on the foregoing model, *T*=technology, *I*=impact, *P*=population, and *A*=affluence. Thus,

$$ln\ I_t = \alpha_1 + \ \beta_2 lnP_t +, \gamma_3 lnA_t + \delta_4 lnT_t + \mu_t, \qquad (2)$$

Shin et al. (2011) ingeniously applied NARDL to estimate the unemployment-output relationship and the adjustment of retail prices of gas. In a simple NARDL framework, Dhaoui et al. (2017) employed NARDL in financial time series analysis based on the EGARCH model and regime-switching model. From the foregoing, it was observed that the literature acknowledges that FDI creates and enables new technology (Stefanovic, 2008), increase spillover effect (Blomström and Kokko, 2000; Borensztein et al., 1998; Sjöholm, 1999; UNCTAD, 2000), accelerate technology transfer linkages for firms (Grossman and Helpman, 1991; Lim, 2001; Smarzynska Javorcik, 2004). Therefore, this study utilized NARDL to examine the FDI migration and climate change nexus. Given the STIRPAT analytical framework underpinning FDI migration and climate change nexus. FDI migration into developing is conceptualized as technology to squarely align this paper to the pollution haven-halo hypotheses debate.

Model Specification

Thus, based on the theoretical framework,

Climate change "scare"=*f*(FDI migration, μ_t) (3)

Expanding Eq. (3) to reflect the STIRPAT model in Eq. (2). It is pertinent to assert that the impact of the population (POP) and affluence proxy by GDP per capita (GDPC) is held constant, while technology proxy by FDI migration is allowed to assume two forms namely positive and negative FDI. The effect of the population has a distinctive impact on Nigeria and Sierra Leone in modelling climate change. For estimation reasons and second-order condition effect, the population is incorporated in Nigeria and silent in Sierra Leone (see Eq. (9) and Eq. (10)). This clarification is imperative to squarely bring us to speed the country-specific modelling framework employed in this paper.

$$CCS_t = \overline{P_t A_t} FDI_t \qquad (4)$$

The general form of the NARDL model can be, as follows:

$$CCS_t = \alpha_1 + \beta_2 POP_t + \gamma_3 GDPC_t + \delta_4 FDI_t^+ + \delta_5 FDI_t^- + e_t \qquad (5)$$

where CCS is used as the regressand, FDI is the FDI inflow is the regressors, $\delta = (\alpha_1, \delta_4, \delta_5)$ is a vector of long-term parameters to be estimated. From Eq. (5), the $FDI_t^+ and\ FDI_t^-$ are the partial sums of positive and negative changes in FDI inflow. The partial sum behavior of FDI is fully captured in Calvo and Reinhart (2000), Mody and Taylor (2013), and Rodrik and Velasco (2000). In NARDL, the partial sum decomposition is calculated, as follows:

$$FDI_t^+ = \sum_{i=1}^{t} \Delta FDI_t^+ = \sum_{i=1}^{t} max\ (\Delta FDI_i, 0) \qquad (6)$$

$$FDI_t^- = \sum_{i=1}^{t} \Delta FDI_t^- = \sum_{i=1}^{t} min\ (\Delta FDI_i, 0) \qquad (7)$$

Based on partial sum decomposition of FDI in Eq. (6) and Eq. (7), Eq. (5) can be integrated into an ARDL form, as follows:

$$\Delta CCS_t = \alpha_1 + \beta_2 POP_t + \gamma_3 GDPC_t + \delta_4 FDI_t^+ + \sum_{i=0}^{q} (y_i^+ \Delta FDI_{t-1}^+ + y_i^- \Delta FDI_{t-1}^-) + \mu_t \qquad (8)$$

In Eq. (8), ρ and q are the lag order; $\delta_4 = \frac{-\delta_4}{\alpha_1}$ and $\delta_5 = \frac{-\delta_5}{\alpha_1}$ measures the long-term impact of lagged increase in FDI and decrease in FDI, and $\sum_{i=0}^{q} y_i^+ y_i^-$ measures the short-term impact of the increase and decrease in FDI on CCS.

The NARDL is employed both at *I*(0) or *I*(1). Also, the null hypothesis for this instrument is conducted using Wald test that $\alpha_1 = \delta_4 = \delta_5 = 0$. CCS in the equation is proxy by CO_2 emission. Hence, Eq. (9) and Eq. (10) are adjusted to for Nigeria and Sierra Leone, respectively, as follows:

$$\Delta CO2_t = \alpha_1 + \beta_2 POP_t + \gamma_3 GDPC_t + \delta_4 FDI_t^+ + \delta_5 FDI_t^- + + \pi_6 CO2_{t-1} + \sigma_7 INT_t + \tau_8 BRDM_t + \sum_{i=1}^{\rho} \theta \Delta GHG_{t-1} + \sum_{i=0}^{q} \begin{pmatrix} y_i^+ \Delta FDI_{t-1}^+ \\ + y_i^- \Delta FDI_{t-1}^- \end{pmatrix} + \mu_t \qquad (9)$$

$$\Delta CO2_t = \alpha_1 + \gamma_3 GDPC_t + \delta_4 FDI_t^+ + \delta_5 FDI_t^- + + \pi_6 CO2_{t-1} + \sigma_7 INT_t + \tau_8 BRDM_t + \sum_{i=1}^{\rho} \theta \Delta GHG_{t-1} + \sum_{i=0}^{q} \begin{pmatrix} y_i^+ \Delta FDI_{t-1}^+ \\ + y_i^- \Delta FDI_{t-1}^- \end{pmatrix} + \mu_t \qquad (10)$$

Eq. (8) was adjusted with INT=interest rate, and BRDM=broad money captured in Eq. (9). In Eq. (9), only FDI was allowed to assume a dynamic asymmetric form. Hence,

1. $\underbrace{+\beta_1 FDI_t^+ + \beta_2 FDI_t^-}$: This function measures the long-run FDI migration, decomposed into dynamic positive and negative FDI.
2. $\underbrace{\sum_{i=1}^{\rho} \theta \Delta GHG_{t-1}}$: This variable is the autoregressive nature of the regressand.
3. $\underbrace{\sum_{i=0}^{q} (y_i^+ \Delta FDI_{t-1}^+ + y_i^- \Delta FDI_{t-1}^-)}$ measures the short-run dynamic FDI migration; and,
4. $\underbrace{\mu_t}$is disturbance term. It is white noise in nature.
5. The difference between model 9 and model 10 is that population (pop) variable was expunged from 10 to enable a stable post-diagnostic test.

Estimation Procedure

The graphical representation of CO_2 emission (a proxy for CCS), FDI migration, population, GDP per capita in selected developing countries are portrayed in **Figure 8-Figure 11**. These trends depict the behavior of changes that had occurred in the hypothesized variables from 1970 to 2019.

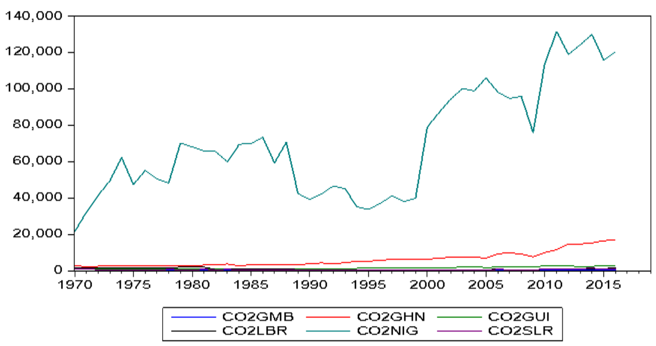

Figure 8. CO_2 trends in selected developing countries

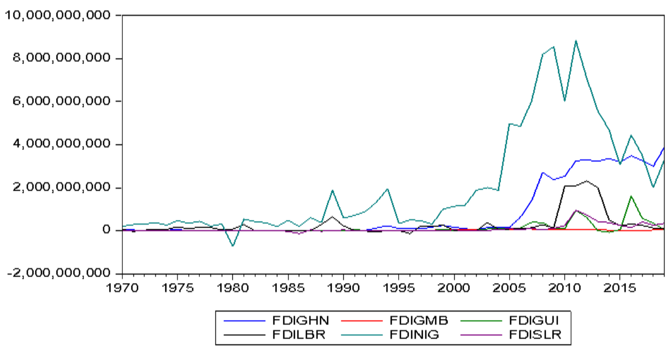

Figure 9. FDI migration trends in some developing countries

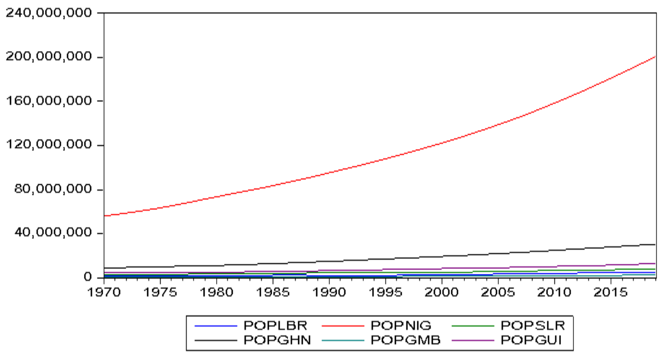

Figure 10. Population trends in selected developing countries

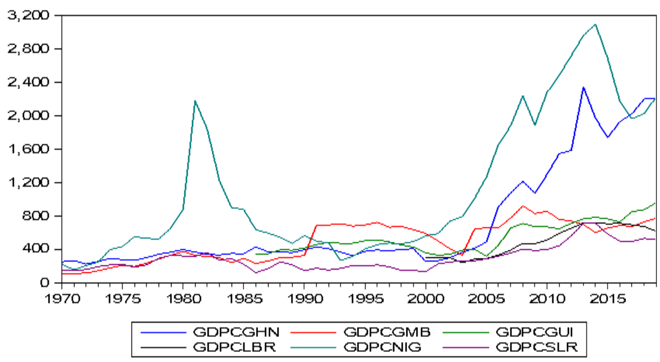

Figure 11. GDPC trends in selected developing countries

The graphical representations depict the existence of a trend. Furthermore, the data were subjected to a unit root test to determine the empirical validity of the variables. The variables were $I(1)$. This implies that the variables were differenced at order 1. Thus, the variables were suitable for NARDL empirical analysis. Before, embarking on demonstrating NARDL in Eviews 9, the VAR system was employed to determine the optimal lag criterion that would be used in defining the lag structure of the NARDL.

RESULTS AND DISCUSSION

The results in **Table 1** show NARDL results that capture the impact of FDI migration on CO_2 emissions in Nigeria and Sierra Leone. From **Table 1**, the bound test showed that there is a long-run relationship between FDI migration and CO_2 emissions in Nigeria and Sierra Leone. This is because the computed F-test is greater than the lower and upper critical

Table 1. NARDL results for Nigeria and Sierra Leone

Nigeria	**CO_2 emission**	
Bound test	6.430232	6
Critical values @ 5%	I0: 2.45	I1: 3.61
Cointegrating equation	-1.072402	[0.0000]
Long-run coefficient		
FDI_positive	-0.000011	[0.0950]
FDI_negative	0.000010	[0.1056]
Post-diagnostic		
Ramsey reset	1.834728	[0.1667]
Heteroscedasticity	0.508939	[0.9000]
Serial correlation LM test	0.893949	[0.4212]
Normality	4.753966	[0.092830]
Sierra Leone	**CO_2 emission**	
Bound test	27.60650	5
Critical values @ 5%	I0: 2.62	I1: 3.79
Cointegrating equation	-1.511756	[0.0000]
Long-run coefficient		
FDI_positive	0.000000	[0.2028]
FDI_negative	0.000000	[0.2739]
Post-diagnostic		
Ramsey reset	0.193460	[0.6640]
Heteroscedasticity	0.791956	[0.6621]
Serial correlation LM test	1.044773	[0.3679]
Normality	0.877883	[0.644719]

Note. Source: Author's computation from Eviews 9; p-values are in parenthesis

bound level at 5%. The bound test is consistent with the cointegrating equation which appeared with the appropriate negative sign and is statistically significant at 5%.

The study observed that the impact of FDI migration on CO_2 emissions into Nigeria and Sierra Leone generated a mixed result. The result showed a non-significant impact. But, the results showed that FDI migration worsens CO_2 emissions in Sierra Leone. The dynamic change in FDI migration led to an infinitesimal positive increase in CO_2 emissions. This implies that pollution haven strictly exists in Sierra Leone. Conversely, in the case of Nigeria, dynamic change in FDI migration caused negative CO_2 emissions (pollution haven issues) and positive CO_2 emissions (pollution halo issues).

The post-diagnostic results showed that the result is effective. The post-diagnostic result is complemented by the CUMSUM and CUMSUM square represented in **Figures 12-15**.

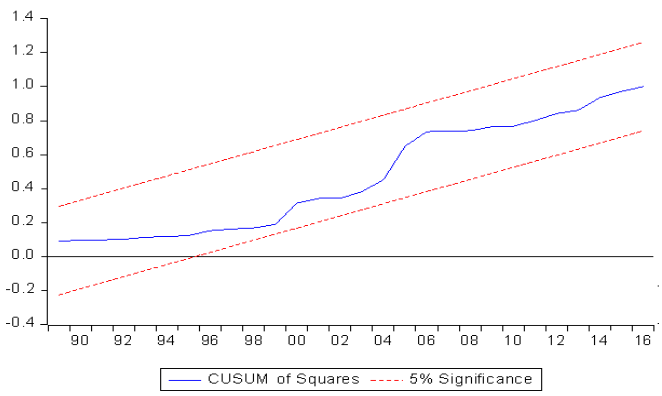

Figure 12. CUSUM square for Nigeria

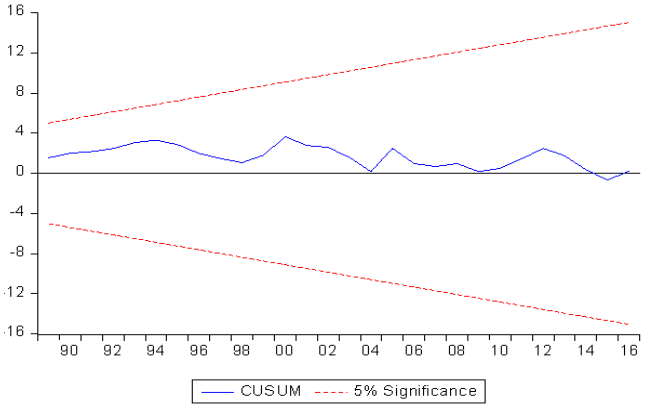

Figure 13. CUSUM for Nigeria

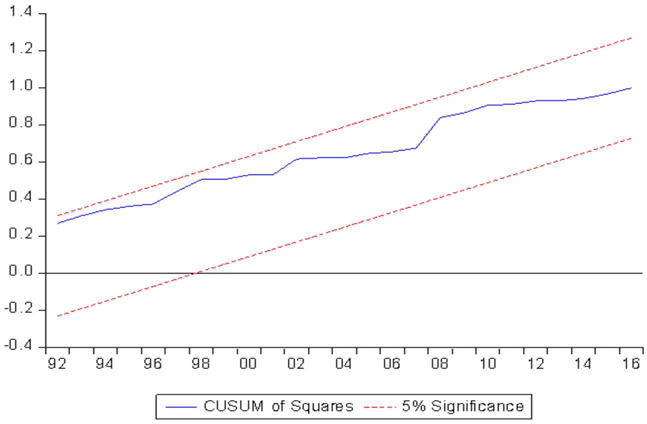

Figure 14. CUSUM square for Sierra Leone

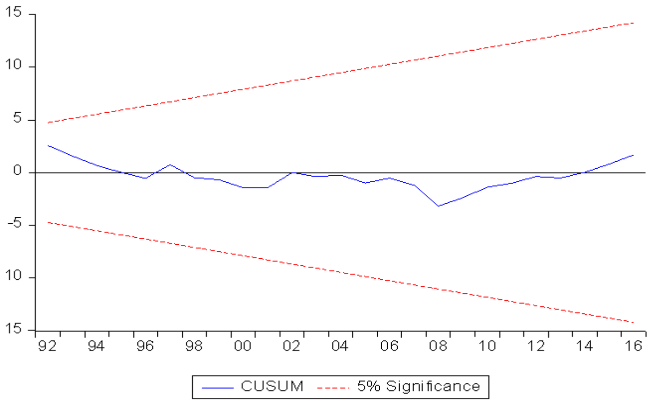

Figure 15. CUSUM for Sierra Leone

WALD test

In a NARDL environment, the Wald F-test could be employed to determine long-run and short-run asymmetries. The null hypothesis at 5% LOS is there is long-run symmetry, the alternative hypothesis states there is long-run asymmetry. The related equational representation and hypothetical statement for Nigeria and Sierra Leone are given below.

Nigeria Wald F-test

Equation

D(CO_2NIG)=**C(1)*D(CO_2NIG(-1))+C(2)*D(FDINIG_POS)**+
C(3)*D(FDINIG_POS(-1))+C(4)*D(FDINIG_POS(-2))+
C(5)*D(FDINIG_POS(-3))+**C(6)*D(FDINIG_NEG)**+
C(7)*D(FDINIG_NEG(-1))+C(8)*D(FDINIG_NEG(-2))+
C(9)*D(GDPCNIG)+C(10)*D(POPNIG)+
C(11)*D(BRDMNIG)+C(12)*D(BRDMNIG(-1))+
C(13)*D(INTNIG)+C(14)

Long-run symmetry hypothesis testing

H0:C(1)=C(2)=C(6)=0
H1:C(1)=C(2)=C(6)≠0

Sierra Leone WALD F-test

Equation

D(CO_2SLR)=**C(1)*D(CO_2SLR(-1))+C(2)*D(FDISLR_POS)**+
C(3)*D(FDISLR_POS(-1))+C(4)*D(FDISLR_POS(-2))+
C(5)*D(FDISLR_POS(-3))+**C(6)*D(FDISLR_NEG)**+
C(7)*D(FDISLR_NEG(-1))+C(8)*D(FDISLR_NEG(-2))+
C(9)*D(BRDMSLR)+C(10)*D(BRDMSLR(-1))+
C(11)*D(GDPCSLR)+C(12)*D(GDPCSLR(-1))+
C(13)*D(INTSLR)+C(14)

Long-run symmetry hypothesis testing

H0:C(1)=C(2)=C(6)=0
H1:C(1)=C(2)=C(6)≠0

Table 2. Wald test (Nigeria)

Equation: Untitled			
Test statistic	**Value**	**df**	**Probability**
F-statistic	2.866830	(3, 28)	0.0543
Chi-square	8.600491	3	0.0351
Null hypothesis: C(1)=C(2)=C(6)=0			
Null hypothesis summary			
Normalized restriction (= 0)		Value	Standard error
C(1)		-0.072402	0.149494
C(2)		-8.59E-06	3.23E-06
C(6)		7.46E-07	3.69E-06
Restrictions are linear in coefficients			

Table 3. Wald test (Sierra Leone)

Equation: Untitled			
Test statistic	**Value**	**df**	**Probability**
F-statistic	7.137063	(3, 25)	0.0013
Chi-square	21.41119	3	0.0001
Null hypothesis: C(1)=C(2)=C(6)=0			
Null hypothesis summary			
Normalized restriction (= 0)		Value	Standard error
C(1)		-0.511756	0.131634
C(2)		2.94E-07	1.17E-07
C(6)		-1.41E-06	5.52E-07
Restrictions are linear in coefficients			

Table 2 and **Table 3** are used to test the hypothesis in Nigeria and Sierra Leone, respectively. The hypothesis in NARDL tests for long-run symmetry and asymmetry between two variables. In this case, this study conducted the Wald F-test at a 5% level of significance. From the F-test in **Table 2**, this study found that there is long-run symmetry between dynamic FDI and CO_2 emissions in Nigeria. Hence, the null hypothesis is accepted.

However, in the case of **Table 3**, the alternative hypothesis is accepted because the F-component is less than 5%. Hence, there is a long-run asymmetry between dynamic FDI and CO_2

emission in Sierra Leone. The implication is that whilst dynamic FDI migration could influence the outcome of CO_2 emissions in the long-run in Nigeria. Conversely, in Sierra Leone, dynamic FDI migration influence on CO_2 emissions is an asymmetry in nature.

CONCLUSION AND POLICY RECOMMENDATIONS

The question of whether exogenous capital migration (proxy by FDI migration) into Nigeria and Sierra Leone generate CCS (proxy by CO_2 emissions) as well as impedes environment quality through technological channels was shown to be ambiguous in Nigeria and Sierra Leone. Based on the statistical properties of the results, the study concludes that the pollution haven hypothesis strictly captures the impact of FDI migration on climate change in Sierra Leone. In the case of Nigeria, both pollution halo and pollution haven hypotheses exist to capture the impact of FDI migration on CCS (proxy by CO_2 emissions) into Nigeria.

This study observed that the change in CO_2 emissions to a 1% change in dynamic FDI is highly infinitesimal. Thus, it is likely also, that FDI migration into Nigeria and Sierra Leone though possess the *apriori* signs to conclude whether pollution haven-halo hypotheses exist. The coefficient of FDI positive (increase) and FDI negative (decrease) is zero. These findings could mean that FDI migration through technology channels insignificantly generates pollution or industrial emission that increases CO_2 emissions. Also, the zero coefficient of FDI migration simply connotes that FDI migration is zero emitters in Nigeria and Sierra Leone. In **Figure 3**, Sullivan et al (2019) CVI revealed that Nigeria is a high-risk country. However, from the coefficients in **Table 1**, we conclude FDI migration is an insignificant and non-primary contributor to CVI in Nigeria.

Evidence from Sierra Leone in **Table 1**, this study adduces that FDI migration into Sierra Leone is consistent with Polloni-Silva et al. (2021), Sarkodie and Leirvik (2020), and Singhania and Saini (2021). Evidence from Doytch and Uctum (2011) states that FDI inflow into the service sector and poor economies align with the halo effect hypothesis. Similarly, Shahbaz et al. (2015) posit that FDI increases environmental degradation. However, the mixed results, in the case of Nigeria, imply the likelihood of pollution haven issue in Nigeria. Thus, advocacy for effective legislation on environmental control in Nigeria and Sierra Leone would ensure that MNCs adopts green technology financing and green technology transfer. This study recommends the formulation of a robust policy that would incentivize external technology financing that improves environmental quality in Nigeria and Sierra Leone.

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Ethics approval and consent to participate: Not applicable.

Availability of data and materials: All data generated or analyzed during this study are available for sharing when appropriate request is directed to corresponding author.

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