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Re-examining the roles of economic globalization and natural resources consequences on environmental degradation in E7 economies: Are human capital and urbanization essential components?

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ABSTRACT

The impacts of economic globalization on environmental degradation are investigated in the E7 economies in the presence of some control variables including economic growth, natural resources, urbanization, and human capital between 1990 and 2016 in a carbon-income environment. This study implements a panel regression analysis using the Augmented Mean Group (AMG) estimator of Eberhardt and Bond and Eberhardt and Teal method for the long run estimation. Besides, the study also applies the fully modified ordinary least square (FMOLS) and dynamic ordinal least square (DOLS) to estimate the long-run relationship between the variables using both CO_2 emission and ecological footprint (ECF) as dependent variables in distinct models. Key important results from the study stand out. Firstly, the study reveals that globalization is negatively correlated with CO_2 emission and the ecological footprint of the E7 economies. This finding depicts the significance of economic integration among countries as a significant tool for cushioning environmental degradation. Secondly, the study demonstrates that natural resources, urbanization, and economic growth increase pollution in both models. Thirdly, human capital reduces environmental pollution in the E7 and its pollution abating impacts also cushion environmental degradation from growing urbanization as the interaction between both variables significantly abates pollution in the E7 bloc. Overall, the study suggests some policy ideas including the establishment of clean discovery regulation and the implementation of conservation initiatives, enhanced human capital investment initiatives, and carefully designed economic integration policies to attract foreign investors with innovative technologies to maximize environmental pros of the era of globalization.

1. Introduction

Globalization primarily involves the process of interacting with the rest of the world. It often occurs in different perspectives including but not only limited to information sharing, mindset development, technology transfer, economic interdependency, and general lifestyle of people. Globalization has been developing at a rapid pace in the last few decades especially as many countries strive for expansion of their economic activities to improve the general welfare of the society (Urata, 2002; Hirst et al., 2015; Broner and Ventura, 2016). As a result, the impacts of globalization are being increasingly felt in many facets of human lives ranging from its impacts on an increase in investment levels to transfers of technology among nations, and also from the expansion of employment to the acceleration of consumption, where all is ultimately expected to converge into higher societal welfare (Brady et al., 2005; Broner and Ventura, 2016).

Although globalization provides benefits to humanity, however, the rise in globalization does not come without its attendant undesirable consequences. In this regard, we would focus on its impact on environmental quality and sustainability as the environment has become

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part of the major aspects of human life that are being influenced by globalization in recent times. Panayotou (2000) has observed that although globalization accelerates structural change and aids developmental processes, it however poses significant concerns especially on the issue of deteriorating environmental quality given the growing threats of the rising level of pollution.

Globalization-driven economic activities that are been executed irresponsibly could pose negative consequences to the environment (Walter and Ugelow, 1979; Dunlap and Jorgenson, 2012). A well-known example in the era of globalization is the issue of global warming which has been linked to several causes including irresponsible industrial activities and conventional energy consumption that have led to higher pollution via greenhouse gas (GHG) emission (IPCC, 2018). Data from the World Bank show that carbon dioxide emission in the world remains in the increasing trend, as emission level increases by 52.54% from 2986 metric tons per capita in 1961 to 4555 metric tons per capita in 2016 (WDI, 2020). Thus, understanding significant factors that affect environmental degradation in a rapid era of globalization should be considered essential.

Studies investigating factors influencing environmental degradation especially globalization are widespread. However, the findings varied across approaches and samples of studies. For example, some studies demonstrate that globalization is pollutant-inducing (e.g., Rafidandi and Usman, 2019; Acheampong et al., 2019; Ahmed et al., 2020; Kwbena et al., 2016; Onifade et al., 2021a; and Tawiah et al., 2021 among others). In contrast, some other studies delivered a finding where globalization is pollutant-reducing. In other words, their findings show that globalization can improve environmental quality (e.g., Nathaniel et al., 2020; Khan et al., 2019; Shahbaz et al., 2017; and Asghar et al., 2020 among others). On the other hand, some other studies delivered finding that fall in between the aforementioned two categories, where globalization has no significant impact on pollution, for instance in the study of Salahudin et al. (2018). Thus, even the growing literature has not reached a consensus regarding the impact of globalization on pollution. Also, despite the widespread progress of research in this area, the issue of the perceived nexus between globalization and environmental degradation does not seem to correlate with the increasing trend of carbon emission globally. This reflect the necessity of not addressing the subject matter in an isolation but rather ensure that other factors are accounted for in such analysis. Besides, the link between research and policy formulation, in reality, should be strengthened by further research contributing new ideas and innovation as crucial element towards promoting effective policy in reducing carbon emission in the future.

Hence, this study intends to contribute to the literature development by juxtaposing the roles of economic globalization and natural resources consequences on environmental degradation. The juxtaposition was not carried out in isolation as provisions were made to explore the roles of human capital, natural resources, and urbanization thereby bridging research gap for the E7 economies as a single bloc. The sample used in the study is drawn for the period between 1990 and 2016 from the E7 economies including China, India, Russia, Mexico, Brazil, Turkey, and Indonesia. Another crucial motivation for the study to utilize the E7 countries as a sample rest on their emerging economic status where economic development is highly progressing and potentially put their environmental quality in a vulnerable condition given the energy dynamics amidst rapid globalization in contemporary times. Two main dependent variables are utilized in the study to represent environmental degradation within the framework of the applied econometric techniques, namely, carbon dioxide emission and ecological footprint. As for globalization, the study utilizes the KOF globalization index as a proxy while GDP per capita represents the level of economic growth. The ratio of urban population to total population acts as the urbanization proxy while total natural resource rent and human capital index act as a measure of natural resources and human capital respectively. In addition to the control variables, the study features an interaction between human capital and urbanization in the estimated equation. Some important results from the study stand out. Firstly, the study reveals that globalization is negatively correlated with CO2 emission and the ecological footprint of the E7 economies. This implies that, in the long run, globalization is statistically significant in reducing pollution. Secondly, the study demonstrates that natural resources, urbanization, and economic growth increase pollution in both models. Thirdly, the study also reveals that human capital is important factor for enhancing environmental quality.

This study is structured as follows. The first section is the introduction. The second section is the literature review. The third section is the methodology, including variable definition and model design. The fourth section includes results and analysis while the final section concludes the study with policy directives.

2. Literature review

2.1. Globalization and environmental degradation: A theoretical synopsis

Several theories in the energy literature have provided possible underpinnings for the nexus between globalization and the environmental degradation and many extant studies have explored the validity of the inherent views that the some of the theories postulate (Balsalobre-Lorente et al., 2019; Terzi and Pata, 2019; Antweiler et al., 2001; Destek and Okumus, 2019; Tawiah et al., 2021). Among some of the theories are the pollution haven hypothesis and the pollution halo hypothesis. The assertions behind the pollution haven hypothesis intensified around the late 1970s when Walter & Ugelow (1979) argued that trade and foreign investment that thrives on the ambient of globalization are creating avenues for shifting pollution intensive production abroad.

The pollution haven hypothesis has increasingly grown to become one of the prominent bases for critiquing globalization with respect to its impacts on environmental degradation around the globe and the debate on its validity is still open for more research in the empirical literature (Antweiler et al., 2001; Terzi and Pata, 2019; Tawiah et al., 2021). However, while the growing arguments for the pollution haven hypothesis persists, another argument came on board by Birdsall and Wheeler (1993) commonly referred to as the pollution halo hypothesis.

The pollution halo hypothesis is diametrical in view to the pollution haven hypothesis regarding the roles of globalization on environmental quality. It posits that globalization, rather than being a means for transferring pollution intensive plants abroad, is a means for achieving cross country technological transfer between developed countries and the developing ones. The idea is that the latter group of countries are expected to benefit from technological acquisition from the former which will translate into gains in terms of better environmental quality and lower degradation (Birdsall and Wheeler, 1993; Balsalobre-Lorente et al., 2019; Tawiah et al., 2021). The validity of the pollution halo hypothesis is still open for more research as there are mix evidence in the empirical literature just as in the case of the pollution haven hypothesis (Destek and Okumus, 2019; Balsalobre-Lorente et al., 2019; Ahmad et al., 2021). Hence, the discussion on the environmental impacts of globalization is still subject to more empirical scrutiny.

2.2. Review of empirical studies

To have a better understanding of the linkage between globalization and the environment, some authors have investigated these variables in extant studies. It is worth noting that although globalization is generally defined in similar terms across countries, however, it is proxied differently when it comes to the issue of modeling and empirical analysis. And as such, most of the available empirical studies have come up with diverse findings. For example, Nathaniel et al. (2020) explored the relationship between globalization and environmental degradation by incorporating other variables such as natural resources and urbanization. The study was taken with a sample of Latin American and

Caribbean countries from 1990 to 2017. Their study demonstrates that globalization positively influences environmental quality. However, their study also revealed that economic growth is a major cause of pollutant emission in most Latin American and Caribbean countries. Similar to Nathaniel et al. (2020), the studies of Rafidandi and Usman (2019), and Salahudin et al. (2018) also measure globalization using the KOF index. Rafidandi and Usman (2019) investigate the nexus of globalization and environmental degradation in Southern African countries between 1971 and 2014 by incorporating energy use as a control variable. The study implements the Maki-cointegration test, combined with ECM regression through the ARDL approach. Based on the estimations, the study demonstrates that in the short-run, globalization drives up carbon emissions. However, in the long-run, it is pollutant reducing. Hence, their finding partially contradicts the result from Nathaniel et al. (2020) by demonstrating globalization's detrimental impacts in the short run.

On the other hand, the study of Salahudin et al. (2018) examines the relationship between globalization and environmental degradation in Sub-Saharan African countries by taking urbanization, energy poverty, and economic growth into account. In this study, environmental degradation is approximated using carbon dioxide emission. In a similar approach to many other studies, economic growth is approximated using GDP per capita, urbanization follows the share of urban population, and globalization is measured by the globalization KOF index. Using the dynamic pooled mean group regression technique, the study reveals that globalization is not significant in affecting carbon emission. Hence, when comparing the findings from Nathaniel et al. (2020), Rafidandi and Usman (2019), and Salahudin et al. (2018), it is clear that there is no consistent relationship between globalization and the environment across studies.

Besides the globalization KOF index, researches for understanding the link between globalization and environmental degradation are also conducted by using some economic variables as proxies for globalization. For example, in a study by Onifade et al. (2021a), trade openness was utilized to explore the impacts of globalization on environmental quality among Turkey and countries in the Caspian region. They used the dynamic ordinary least squares (DOLS) technique and the fully modified ordinary least squares (FMOLS) technique in their analysis and observed that globalization is pollutant-inducing among these countries. In another study by Acheampong et al. (2019), globalization was measured by foreign direct investment and trade openness. As for environmental degradation, the study uses carbon emission. In estimating the impacts of these variables, the study applies panel regression with fixed effect and random effect and also implements an instrumental variable GMM estimator to produce consistent estimates. The study demonstrates that globalization is pollutant-inducing, which contradicts the findings from Nathaniel et al. (2020) and that of Rafidandi and Usman (2019). In a different study, Joshua et al. (2020) also utilize foreign direct investment to measure globalization in the case of the South African economy. The study covers data from 1970 through 2017 and estimations were done using the ARDL bounds testing procedure. However, their study demonstrates that FDI, which represents globalization, poses positive effects to environmental quality and this impact is valid in the short-run and long run. In addition to the finding on globalization, the study also reveals that urbanization does not significantly induce carbon emission in the short run. However, it does affect in the long run. Hence, their finding also contradicts the study from Acheampong et al. (2019) and Onifade et al. (2021a) regarding the argument that globalization is pollutant-inducing, but is in line with Nathaniel et al. (2020) and Rafidandi and Usman (2019).

Another proxy of globalization using a foreign direct investment approach can be seen in the study of Khan et al. (2019) for the Pakistani economy between 1971 and 2016. Carbon emission is utilized in the study to measure environmental degradation, while annual urban population growth represented urbanization. Using the dynamic ARDL model as a primary method of estimation, the study demonstrates that globalization contributes to the falling carbon emission level in Pakistan. Also, the study features some other significant factors such as urbanization and per capita GDP. This positive impact is similar to the findings from Joshua et al. (2020), Nathaniel et al. (2020), and Rafidandi and Usman (2019). A similar finding is also revealed from Shahbaz et al. (2017) and Zaidi et al. (2019). Shahbaz et al. (2017) studied the impact of globalization on carbon emission in Japan during 1970–2014. The finding shows that globalization reduces carbon emission in the short run. On the other hand, Zaidi et al. (2019), taking Asian Pacific countries from 1990 to 2016 as a sample, demonstrates that globalization is pollutant-reducing, regardless of whether in the short-run or the long-run. This finding is in contrast to that of Kwbena et al. (2016) with the sample of 26 sub-Saharan African countries from 1990 to 2013. Based on their study, the effect of globalization on the environment is detrimental.

Besides globalization, some authors have also utilized other variables to understand the factors inducing environmental degradation. Some of the important variables linked to environmental degradation aside from economic growth include urbanization, natural resources rent, population, environmental regulation, and human capital (Ahmed et al., 2020; Ali et al., 2019; Nathaniel et al., 2019; Hassan et al., 2018; Gyamfi et al., 2021b). For instance, Ahmed et al. (2020) investigate whether urbanization and economic growth play a role in reducing environmental quality in China. Urbanization and economic growth are proxied by urban population growth and per capita GDP, respectively. As for environmental degradation, the study utilizes the ratio of natural resources to GDP as a proxy. Using ARDL as the primary method of estimation, the study demonstrates that urbanization and economic growth worsen environmental quality but human capital is found to have the power to moderate the negative impact. Interestingly, the study found that interaction environmental quality is improving when human capital interacts with urbanization.

Khan et al. (2021) investigate whether natural resources, energy consumption, and population growth are significant determinants of ecological footprint and environmental degradation in the US between 1971 and 2016. Using the generalized method of moment (GMM) and robust least-squares, the study demonstrates that natural resources have a negative relationship with ecological footprint and carbon emission. Furthermore, population growth is positively correlated with ecological footprint and carbon emission, meaning that a higher growing population tends to use more energy and thus emits more carbon, which degrades the environment. Danish et al. (2019) also analyze how natural resources and carbon emission are related in BRICS countries. In this case, carbon dioxide emission is utilized to measure environmental degradation. The study runs panel regression using robust panel data estimator AMG algorithm over the sample period from 1990 to 2015. Based on this estimation technique, the study demonstrates that natural resource abundance diminishes carbon emission in Brazil, South Africa, China, and Russia but it generates pollution in South Africa.

Our study is unique on the front of variables selection which is apparently in line with the United Nations Sustainable Development Goals (UN-SDGs) agenda to be achieved by 2030 which is very limited in the extant literature for the case of emerging economies under review. The SDG goals boarders around climate change mitigation (SDG-13), sustainable development (SDG-8), human anthropogenic activities among others in a carbon-income environment. Hence, given the overwhelming mix of evidence in the literature understanding the significant factors that affect environmental degradation in a rapid era of globalization is considered essential. As such, this study provides an empirical analysis of the subject matter within the context of the E7 economies in a carbon-income environment. Finally, the current study is built on second-generational panel analysis, that circumvent for the short comings of first-generational methods such as cross-sectional problem and heterogeneity issues. Thus, making estimates and coefficients from second-generational estimators robust for policy crafting and guidance.

3. Methodology

3.1. Data sources and variable description

Using data observation between 1990 and 2016, the study explores the roles of economic globalization in environmental degradation in the E7 economies. Both CO_2 emissions and ecological footprint were adopted as measures of environmental degradation to create a comprehensive analysis of the impacts of economic globalization on environmental degradation in the E7 economies while juxtaposing the roles of human capital and urbanization among the countries. The full descriptions of the variables are provided with their corresponding measurements and sources in Table 1. Given the strong appealing arguments in contemporary studies concerning the crucial roles of natural resource rent in economic globalization process among countries (Sinha and Sengupta, 2019; Khan et al., 2021; Nathaniel et al., 2021; Sarkodie and Adams, 2020; Gyamfi et al., 2020a; Guan et al., 2020), this study also accounts for the impact of resources rent in the current empirical analysis for the E7 economies.

Although there has been a rise in the amount of study on the initiatives to combat global warming and ecological deterioration, however, the fundamental environmental concerns do not seem to decline as anticipated. As such, to monitor the degradation of the ecosystem, there is a growing necessity to examine other factors beyond the conventional energy consumption level. Such factors include the roles of human capital and urbanization amidst rising economic globalization among countries. The reality is that previous studies have established that there is a connection between ecological sustainability, pro-environmental behavior, and human capital index. Chankrajang and Muttarak (2017) stated that the conduct of humankind affects the use of clean energy. However, UNESCO (2010) stressed the major role played by emission mitigation and global warming regulation. The promotion of energy conservation (Bano et al., 2018), as well as reduced deforestation, performs a crucial function in reducing CO_2 pollution (Godoy et al., 1998). This analysis, therefore, addressed the influence of human capital in the E7 economy on Carbon emission. We however assume that in the E7 economics, human capital would have an adverse association with Carbon emission.

Moreover, natural resources exploitation includes practices such as mining and deforestation that can contribute to Carbon pollution Also, the use of natural resources in the context of coal, oil, and natural gas is ecological degradation (Danish et al., 2019). Natural resources are expected to be positively linked to Carbon pollution in E7 since the area relies strongly on its polluting natural resources to meet national intake and energy requirements. Globalization expands the economies and enables the ingress of goods and innovations that could boost consumer's well-being or build on established scales of pollutants (Sinha and Sengupta, 2019). This required that globalization be included in the framework. Globalization can support minimize or raise the deterioration of the ecosystem. In the context of globalization, the connection to ecological destruction may be favorable or unfavorable (Gómez and Rodríguez, 2019). Globalization may, nevertheless, worsen ecological deterioration in the E7 due to extreme regional poor ecological standards.

Economic growth may contribute to Carbon emission as growth is increased (mainly fossil fuel) energy usage as well as natural-resource which may cause ecological pressures The E7 economies have witnessed pretty steady growth across the past years along with rising Carbon pollution (Gyamfi et al., 2021a) thus, the economic impacts on CO_2 pollution in the E7 economies need to be examined. Economic growth is forecast to expand Carbon pollution in E7 economies since economic advancement in the area is based on energy and natural resources. Most energy emerges from burning fossil fuels energy source which dominates in the energy mix in the investigated blocs.

Table 1
Description of variables.

VARIABLES	MEASUREMENTS	SOURCES	SYMBOLS
CO_2 Emissions	Metric tons per capita	WDI (2020)	CO_2
GDP per Capita	In constant 2010 USD	WDI (2020)	GDP
Urbanization	Urban population (% of the total population)	WDI (2020)	UB
Natural resources	Total natural resource rent (% of GDP)	WDI (2020)	NRR
Economic Globalization	KOF globalization Index	KOF index	EG
Ecological Footprint	Global hectares per capita	GFN (2020)	ECF
Human capital	Human capital index	Penn World Table	HC
Interaction term	(Human capital × urbanization)	WDI (2020)	HIB

Sources: author's compilation, 2020. Note GFN Global footprint network.

3.2. Model

The STIRPAT structure is the foundation of this analysis. The STIRPAT model of Rosa and Dietz (1998) is a stochastic model that was developed as an extension to the traditional IPAT model of Ehrlich and Holden (1971) and Ehrlich and Holden (1972). The IPAT model shows that the destructions of the ecosystem (I) are inherently economically and socially related as they can be explained by the population component (P), affluence (A) -in terms of economic activities or production, and technology (T). However, there is a major weakness in the IPAT structure since T is often unknow as it values depend on other components in the model thereby prompting a stochastic modification (Rosa and Dietz, 1998). Hence, the modified IPAT model (i.e, STIRPAT) has been widely utilized as an accounting model in the literature to explore the impacts of human activities on the environment (Wei, 2011; Bello et al., 2018; Jia et al., 2009).

$$I_t = \vartheta_0 P_t^{\xi 1} A_t^{\xi 2} T_t^{\xi 3} \mu_t \tag{1}$$

Equation (1) represent the STIRPAT model where I is a pointer of ecological degradation, while P, A, and T represent the population inhabiting a place, the level of wealth, and the level of technological innovation respectively. On the other hand, ϑ_0, ξ1, ξ2, and ξ3 are the factor evaluators, while μ represents the error term. The introduction of the error term makes the traditional IPAT model stochastics since the variable T largely covers all other unknown varibles. Hence, T may be broken down based on the purpose of the study (Bello et al., 2018; Anser, 2019; Nathaniel et al., 2020). Base on the analysis of Solarin and Al-Mulali studies (2018) and Nathaniel et al. (2020), I, in the current analysis, is identified by two environmental factors namely carbon emission and ecological footprint. P and A, are denoted by economic sustainability on the other hand. Then, we adopted urbanization (UB), natural resources rent (NRR), economic globalization (EG), human capital (HC), and interaction terms (Human capital × urbanization (HIB)) as proxies for T. Thus, the extended layout is shown in Eq. (2) with the logarithm representation in Eq. (3).

$$I_t = \vartheta_0 GDP_t^{\xi 1} EG_t^{\xi 2} HC_t^{\xi 3} UB_t^{\xi 4} NRR_t^{\xi 5} HIB_t^{\xi 6} \mu_t \tag{2}$$

$$LnI_{it} = \alpha_0 + \alpha_1 LnGDP_{it} + \alpha_2 LnEG_{it} + \alpha_3 LnHC_{it} + \alpha_4 LnUB_{it} + \alpha_5 LnNRR_{it} + \alpha_6 LnHIB_{it} + \varepsilon_{it} \tag{3}$$

From Eq. (2) and Eq. (3), GDP, EG, HC, UB, NRR, and HIB denote economic growth, economic globalization, human capital, natural resources rent as well as an interaction term between human capital and urbanization. Given the evidence for possible detrimental effects of urbanization on the environment in the literature (Salahuddin et al., 2019; Nathaniel et al., 2019; Onifade et al., 2021b), and considering that human capital connects with other demographic factors like urbanization, the use of an interaction term was conceived to explore whether human capital has any moderating function in the urbanization-environment nexus. *I*, on the other hand, represents the two environmental indicators used in this analysis, thus, CO_2 pollution and ecological footprint. To analysis the impact of the variables on I, we formulated Eq. (4) and Eq. (5).

$$LnCO2_{it} = \alpha_0 + \alpha_1 Ln\text{GDP}_{it} + \alpha_2 Ln\text{EG}_{it} + \alpha_3 LnHC_{it} + \alpha_4 Ln\text{UB}_{it} + \alpha_5 Ln\text{NRR}_{it} + \alpha_6 Ln\text{HIB}_{it} + \varepsilon_{it} \tag{4}$$

$$LnECF_{it} = \alpha_0 + \alpha_1 Ln\text{GDP}_{it} + \alpha_2 Ln\text{EG}_{it} + \alpha_3 LnHC_{it} + \alpha_4 Ln\text{UB}_{it} + \alpha_5 Ln\text{NRR}_{it} + \alpha_6 Ln\text{HIB}_{it} + \varepsilon_{it} \tag{5}$$

In Eq. (4) and Eq. (5), CO_2 and ECF represent CO_2 emission and total ecological footprint respectively whereas the remaining variables maintain their original description.

3.3. Cross-sectional dependency test and panel unit root analysis

Firstly, as a major step into choices of the methodological framework for the current study vis-à-vis the possibility of interdependence among the E7 economies, we have ensured that a cross-sectional dependency (CD) test was conducted. Contemporary studies have vastly enunciated the significance of such action as an important step towards ensuring not just the right model selection but also to ensure the robustness of estimated coefficients for a panel study where analysis is done on observations that are drawn from samples that are bound to be cross-sectionally dependent (Shahbaz et al. 2018, 2019; Gyamfi et al. 2021a, 2021b; Wang et al., 2020; Shen et al., 2021). To this end, we adopted Pesaran (2007) CD test, and the Pesaran (2015) test for the cross-sectional dependency test. The conducted CD test provided evidence of cross-sectional dependence in the panel analysis and this primarily implies that conducting a direct unit-root test using the first-generation techniques without factoring in the possibility of cross-sectional dependence would have resulted in an exercise in futility (Im et al., 2003). Consequently, we applied the second generation IPS (CIPS) unit root test of Pesaran (2007) following the model in equation (6).

$$\Delta \text{Y}_{it} = \Delta \varphi_{it} + \beta_i \text{X}_{it-1} + \rho_i T + \sum_{j=1}^{n} \theta_{ij} \Delta \text{X}_{i,t-j} + \varepsilon_{it} \tag{6}$$

In equation (6), X_{it} stands for the understudied variables while φ_{it} and T are the intercept and time span respectively. Δ and ε_{it} are difference operator and model error term accordingly. In addition to the CIPS results, the panel IPS results were reported to double-check the results from the CIPS concerning the stationarity nature of the variables.

3.4. Panel cointegration analysis

To bypass the pitfalls in using first-generation cointegration approaches in testing for cointegration in presence of cross-sectional dependence, we have adopted the Westerlund (2007) technique to examine the long-run relationship among the variables. The application of the approach for cointegration checks follows the steps for error adjustment process in equation (6).

$$\Delta \text{Y}_{it} = \delta_i \text{d}_t + \varphi_i \text{Y}_{it-1} + \lambda_i \text{X}_{it-1} + \sum_{j=1}^{pi} \varphi_{ij} \Delta \text{Y}_{i,t-j} + \sum_{j=0}^{pi} \gamma_{ij} \Delta \text{X}_{i,t-j} + \varepsilon_{it} \tag{7}$$

In equation (7), $\delta_t = (\delta_{i1}, \delta_{i2})'$, $d_t = (1, t)'$, and φ present a vector for the parameters, the deterministic terms, and the error adjustment term respectively. Identifying the long-run relationship is simply based on the produced group mean statistics and the panel statistics following the least square estimation of the φi parameter in equation (7).

3.5. Long-run panel coefficient estimation techniques

This study adopted the Augmented Mean Group (AMG) estimator of Eberhardt and Bond (2009) and Eberhardt and Teal (2010) for the long-run panel estimations. In addition, while we focus on the AMG estimates due to its statistical strengths that have triggered the rise in its application in contemporary studies (Nathaniel et al., 2021; Wang et al., 2020; Gyamfi et al., 2020), we also utilized the fully modified ordinary least square (FMOLS), and dynamic ordinal least square (DOLS) to estimate the long-run coefficients as these two other techniques have received substantial attention as robustness checks in the past (Maji et al., 2020; Guan et al., 2020; Sulaiman et al., 2020).

$$\Delta Y_{it} = \alpha_i + \beta_i \Delta X_{it} + \sum_{t=1}^{T} \pi_t D_t + \varphi_i UCF_t + \mu_{it} \tag{8}$$

$$\text{AMG} = \frac{1}{N} \sum_{i=1}^{N} \varphi_i \tag{9}$$

Given the panel variables Y_{it} and X_{it} with the time-variant dummy variable in equation (8), the difference operator is denoted by Δ while *UCF* captures the unobserved common effects. The ordinary least square outputs of equation (8) help to produce the AMG estimator in equation (9) given that φ_i represents the slope parameters of the variable X_{it}.

4. Results and discussion

4.1. Preliminary tests results

We present the summary statistic and the correlation matrix of the variables in Table 2 while the outputs of the Cross-sectional dependency (CD) test were presented in Table 3. It can be seen that there is a positive correlation between CO_2 and economic globalization (EG), human capital (HC), urbanization (UB), and natural resource rent (NRR). The obtained positive correlation is strong except in the case of NRR. The correlation matrix for the ECF also follows similar outcomes to that of the CO_2 model.

A look at the results in Table 3 shows that the conducted CD test provided evidence of cross-sectional dependence in the panel analysis since there is enough evidence to reject the null hypothesis that supports an independent cross-section for the variables in the panel study. Hence, the second generation CIPS unit root test of Pesaran (2007) was reported for the variables in the study in Table 4 before providing a panel cointegration report as shown in Table 5. The unit root results with regards to both IPS and CIPS in Table 4 confirm that the variables are stationary at first difference.

The Westerlund (2007) Cointegration Test results in Table 5 establishes a long-run relationship for the variables in the panel study. The conclusion was supported by the evidence for the rejection of the null hypothesis based on the significance of the obtained group statistics and the panel statistics. Thus, the appropriate panel techniques were applied to obtain the long-run cointegrating coefficients.

4.2. Panel estimation techniques

The results of the AMG panel estimation techniques for the long-run relationships among the variables are presented together with the findings from FMOLS and DOLS approaches in Table 6 (see Table 7).

The long-run estimates in Table 6 present the AMG, FMOLS, and the DOLS outcomes in two folds (based on the two indicators considered measurements of the environment), output based on carbon emission, and the output based on ecological footprint. The outcomes from the robustness analysis, the FMOLS and DOLS confirms the AMG outcome which the studies rely on. From both carbon emission and ecological footprint, economic growth has shown a positive significant linkage. This clearly showed the existence of environmental degradation across

Table 2
Summary statistics and correlation.

	CO_2(Ln)	ECF(Ln)	GDP(Ln)	EG(Ln)	HC(Ln)	NRR(Ln)	UB(Ln)
Mean	1.083	0.686	8.415	3.714	0.815	1.160	4.001
Median	1.013	0.789	8.882	3.846	0.810	1.346	4.198
Maximum	2.637	1.931	9.551	4.705	1.220	3.076	4.454
Minimum	−0.343	−0.244	6.355	2.718	0.396	−2.095	3.240
Std. Dev.	0.777	0.607	0.915	0.395	0.185	1.127	0.390
Skewness	0.304	0.056	−0.763	−0.683	0.306	−0.831	−0.648
Kurtosis	2.273	1.794	2.208	2.823	2.736	3.252	1.884
Jarque-Bera	7.083	11.546	23.308	14.981	3.502	22.295	23.055
Probability	0.028	0.003	0.000	0.000	0.173	0.000	0.000
Sum	204.831	129.758	1590.562	702.054	154.219	219.296	756.375
Sum Sq. Dev.	113.760	69.438	157.663	29.414	6.463	238.897	28.664
Observations	189	189	189	189	189	189	189
Correlation							
	CO_2(Ln)	**ECF(Ln)**	**GDP(Ln)**	**EG(Ln)**	**HC(Ln)**	**NRR(Ln)**	**UB(Ln)**
CO_2(Ln)	1						
ECF(Ln)	0.920a	1					
GDP(Ln)	0.633a	0.537a	1				
EG(Ln)	0.529a	0.516a	0.704a	1			
HC(Ln)	0.827a	0.680a	0.601a	0.652a	1		
NRR(Ln)	0.198a	0.066	−0.131c	0.195a	0.517a	1	
UB(Ln)	0.598a	0.473a	0.975a	0.707a	0.606a	−0.053	1

Note: a, b and c are 1%, 5%, and 10% significant level respectively.

Table 3
Cross-sectional dependency (CD) test results.

	Pesaran(2007) CD Test	Pesaran(2015) LM Test
CO_2(Ln) = f(GDP(Ln), EG(Ln), HC(Ln), UB(Ln), NRR(Ln))	**8.719a**	**−2.475b**
ECF(Ln) = f(GDP(Ln), EG(Ln), HC(Ln), UB(Ln), NRR(Ln))	**14.693a**	**−1.563b**

Note: a, b and c are 1%, 5%, and 10% significant level respectively.

E7 countries because of growing economic activities in the countries. It therefore supports the notion that emerging countries are economically progressing at the expense of environmental pollution from greenhouse emissions on one hand and at the expense of their ecological performance on the other hand. The outcome is in agreement with the findings by (Charfeddine, 2017; Omri et al., 2015; Galli, 2015; Zakari et al., 2020; Gyamfi et al., 2021c) but contradict the results from Li et al., (2020).

For the nexus between economic globalization and environmental degradation, the carbon emission model has shown a negative significant relationship in all empirical approaches. This depicts the significance of economic integration and globalization in cushioning the poor quality of the environment. This shows that opening up to the rest of the world has earned the emerging countries some level of sustainable development thereby attracting foreign investors with innovative technologies which enhance clean economic activities with less carbon economy. This supports the findings from (Rudolph and Figge, 2017; Tawiah et al., 2020). There is also supportive evidence for the cushioning role of globalization on environmental degradation. However, since the ecological footprint comprises of various aspects of environmental damages that is not limited to carbon emission alone, comparing the two models suggest that globalization could pose detrimental effects on ecological footprint as a whole despite being an abating tool for carbon emission.

Furthermore, the outcome obtained from natural resources shows a positive and significant relationship with ecological destruction for both models. This affirms that natural resources encourage pollution within the E7 economics which confirms the studies of Amed et al. (2020) and Hassan et al. (2019). It can be observed that these nations have an amount of income to be used for export and internal usage. This finding, nevertheless, supports the idea that the extraction of natural resources within those nations has never become effective. Excess dependency on natural resources leads to the depletion of biocapacity (Bekun et al.,

Table 5
Westerlund (2007) Cointegration test.

Model/dependent	Group statistics		Panel statistics	
	Gτ	**Gα**	**Pτ**	**Pα**
CO_2(Ln) = f(GDP(Ln), EG(Ln), HC (Ln), UB(Ln), NRR(Ln))	−3.140b	−0.417a	−7.993b	−0.535c
ECF(Ln) = f(GDP(Ln), EG(Ln), HC (Ln), UB(Ln), NRR(Ln))	−2.635c	−0.839a	−9.049a	−1.194c

Note: a, b and c are 1%, 5%, and 10% significant level respectively.

Table 4
Panel IPS and CIPS unit root test.

Variables	IPS				CIPS			
	Intercept		Intercept & trend		Intercept		Intercept & trend	
	Levels	1st Diff	Levels	1st Diff	Levels	1st Diff	Levels	1st Diff
CO_2(Ln)	−1.008	−4.707a	−2.215	−4.638a	−2.826	−4.468a	−2.237	−4.456a
ECF(Ln)	−1.583	−5.814a	−2.616	−5.813a	−1.714	−4.792a	−2.620	−4.860a
GDP(Ln)	−0.160	−3.765a	−2.032	−3.877a	−1.753	−3.041a	−1.345	−3.323a
EG(Ln)	−2.302	−5.015a	−2.095	−5.242a	−2.334b	−4.362a	−2.357	−4.651a
HC(Ln)	−2.449	−2.070b	−0.728	−2.232b	−1.383	−1.954b	−0.840	−2.525b
NRR(Ln)	−1.736	−5.237a	−1.896	−5.208a	−1.918	−5.216a	−2.399	−5.275a
UB(Ln)	−1.324	−3.223a	−0.783	−2.170b	−1.633	−3.214a	−1.040	−2.860b

Note: a, b and c are 1%, 5%, and 10% significant level respectively.

Table 6
FMOLS, AMG, and DOLS results.

Variables	FMOLS	AMG	DOLS
Model 1: Dependent CO_2			
GDP(Ln)	0.277a	0.540b	0.238c
EG(Ln)	−0.039b	−0.049c	−0.041c
HC(Ln)	−11.379c	−15.160c	−3.582c
UB(Ln)	−1.188a	−3.551b	−0.064c
NRR(Ln)	0.034b	0.015a	0.106b
HIB(Ln)	−0.266c	−4.721a	−3.796a
Wald Test		5.30a	
No. of regressors		6	
No. of observation		189	
No. of groups		7	
R^2	0.889		0.799
Model 2: Dependent ECF			
GDP(Ln)	0.027a	0.074a	0.269b
EG(Ln)	−0.039b	0.041b	0.058c
HC(Ln)	−5.624b	−5.942c	−0.432b
UB(Ln)	0.607a	0.734a	1.405b
NRR(Ln)	0.012c	−0.0211c	−0.109
HIB(Ln)	−0.376c	−1.021c	−0.493a
Wald Test		11.62c	
No. of regressors		6	
No. of observation		189	
No. of groups		7	
R^2	0.883		0.799

Note: a, b and c are 1%, 5%, and 10% significant level respectively.

Table 7
The DH Granger causality evidence_

CO_2(Ln) = f(GDP(Ln), EG(Ln), HC(Ln), UB(Ln), NRR(Ln))				
Null Hypothesis	**W-Stat.**	**Zbar-Stat.**	**P-value**	**Remarks**
GDP(Ln)→ CO_2(Ln)	5.670a	3.672	(0.0002)	**Uni-directional**
CO_2(Ln)→ GDP(Ln)	3.746	1.622	(0.1047)	
EG(Ln)→ CO_2(Ln)	2.555	0.354	(0.7229)	**Uni-directional**
CO_2(Ln)→ EG(Ln)	4.861a	2.810	(0.0049)	
HC(Ln)→ CO_2(Ln)	5.390a	3.374	(0.0007)	**Bi-directional**
CO_2(Ln)→ HC(Ln)	4.398b	2.317	(0.0205)	
NRR(Ln)→ CO_2(Ln)	4.923a	2.876	(0.0040)	**Uni-directional**
CO_2(Ln)→ NRR(Ln)	3.692	1.566	(0.1173)	
UB(Ln)→ CO_2(Ln)	6.180a	4.215	(2.E−05)	**Bi-directional**
CO_2(Ln)→ UB(Ln)	5.583a	3.579	(0.0003)	
ECF(Ln) = f(GDP(Ln), EG(Ln), HC(Ln), UB(Ln), NRR(Ln))				
Null Hypothesis	**W-Stat.**	**Zbar-Stat.**	**P-value**	**Remarks**
GDP(Ln)→ ECF(Ln)	9.828a	8.099	(4.E−16)	**Uni-directional**
ECF(Ln)→ GDP(Ln)	2.807	0.623	(0.5331)	
EG(Ln)→ ECF(Ln)	8.323a	6.497	(8.E−11)	**Bi-directional**
ECF(Ln)→ EG(Ln)	14.469a	13.042	(0.0000)	
HC(Ln)→ ECF(Ln))	5.447a	3.434	(0.0006)	**Bi-directional**
ECF(Ln)→ HC(Ln)	3.639	1.509	(0.1313)	
NRR(Ln)→ ECF(Ln)	3.051	0.883	(0.3772)	**Uni-directional**
ECF(Ln)→ NRR(Ln)	3.892c	1.778	(0.0753)	
UB(Ln)→ ECF(Ln)	6.914a	4.996	(6.E−07)	**Bi-directional**
ECF(Ln)→ UB(Ln)	7.492a	5.611	(2.E−08)	

Note: a, b and c are 1%, 5%, and 10% significant level respectively, while → **represents does not** "homogeneously cause".

2019). Additionally, the use and development of agricultural materials promote deforestation which boosts pollutants given the strategic importance of the E7 economies. Besides, some of the nations utilize their natural resources (coal, petroleum & gas) to satisfy their energy demands. It was suggested that the availability of resources would allow a nation independent by decreasing imports of energy and relying on internal energy production with lower pollution (Ahmed et al., 2020).

From the analysis again, human capital lowers pollution for both models. This indicates that human capital has played an important function in the E7 economies with respect to ecological well-being. In recent years, the E7 has worked to develop human resources through better literacy and environmental education. An environmentally oriented human capital would have an increased desire for renewable energy that is essential for environmental protection through energy conservation strategies while utilizing and exploiting natural resources. This result reinforces the observations by Zafar et al. (2019) and Bano et al. (2018) in previous studies. Table 6 again shows that the proportional desirable impacts of human resources override that of natural resources as well as economic activity. This further indicates that E7 should boost human capital development policy and strategies to ensure better protection of the environment.

We also found that urbanization aggravates E7 environmental degradation in the ecological footprint models with moderate complementary results from the carbon emission outcomes as the AMG outcomes for carbon emission was different. On the overall, the ecological footprint model provides more consistent outcomes. These observed discrepancies reflect the likely differences in the explanatory power of the two dependent varibles. The degradation enhancing effect of urbanization from the broad scope of ecological footprint in this study reinforces the results from some extant studies (Salahuddin et al., 2019; Nathaniel et al., 2019; Charfeddine, 2017). Urbanization boosts the economy and expands the density of towns that have minimal resources. Moreover, it also triggers higher demand for transportation, lodging, and household equipment, and so on (Lin and Du, 2015). Given that the energy used by E7 is largely non-renewable, pollution levels are expected to rise. Nevertheless, the goal, however, was to explore whether human capital had a moderating function. The significantly negative factor of the concept interaction is insightful and attractive. The consequence is that human capital lessens the detrimental environmental impact of urbanization. It implies the combination of urbanization and human resources to decrease pollution although urbanization originally raises pollution. This also showed that human capital development is important to urban preservation. Ahmad et al. (2020) had previously verified close connections with China wiles Nathaniel et al. (2020) for the Latin American and Caribbean countries.

4.3. DH granger-causality evidence

The Dumitrescu and Hurlin (2012) Granger causality test was utilized for the causality analysis for the panel variables. Causality analysis for this study would help in showing the true direction of causation among the understudied variables as seen in the procedures in extant studies (Shahbaz et al., 2018; Bekun et al. 2019, 2021; Khan et al., 2021; Onifade et al., 2020; Alola et al., 2019; Çoban et al., 2020).

From the analysis, it can be observed that there is a bidirectional relationship between human capital as well as pollution and urbanization and emission for both models which a bidirectional relationship existed between economic globalization and ecological footprint. On the other hand, a unidirectional relationship was observed between economic growth and pollution as well as natural resources and pollution but a unidirectional relationship was obtained between economic growth and CO_2 emissions.

5. Conclusion and policy recommendations

The study examines the impacts of economic globalization on pollution in the E7 economies from 1990 to 2016 while controlling for the roles of urbanization, human capital, and natural resources. By relying on the AMG technique, we assessed two different models, using CO_2 emission and ecological footprints as the dependent variable for the first and second model respectively. The findings depict the significance of economic integration among countries as globalization cushions environmental degradation by reducing CO_2 emission among the E7. On the other hand, natural resources, urbanization, and economic growth aggravate pollution while human capital reduces environmental destruction among the E7 countries. The desirable environmental impacts of human capital also help as a significant cushioning tool to environmental damage from growing urbanization as the interaction between human capital and urbanization significantly abates pollution in the E7. Thus, these findings, coupled with additional results that showed various causal pathways between the understudied variables, inform the required policy guidelines.

Firstly, conservation initiatives need to be incorporated in E7 economies natural resource exploration and exploitation, as the results show that natural resources increases pollution. This alludes to the method of natural resources exploration which need a revamp to adoption of new technologies. The requirement for "clean discovery" requires that regulations concerning water, soil, and mineral contamination in E7 be implemented and improved. This may not only eliminate emissions but also maintains conservation. consumption of lower carbon-emitting natural resources, such as hydropower and natural gas would enable the restoration of resources, raise biocapacity and lessen the environmental impact with lower degradation of natural resources.

On the other hand, urbanization has many exceptions. The negative environmental consequences of urbanization indicates that the advancement of human capital is a solution for an urban phenomenon and may also lead to determining several different aspects of urban conservation. Improved capitalization facilities and the creation of clever communities are also essential to urban stability and competitiveness. In residential economic developments such as accommodation, energy, and mobility, Smart cities foster performance, creativity, and conservation.

When considering the ecological aspect of globalization beyond carbon emission alone, globalization can be said to be contributing to environmental degradation, we, therefore, suggest that authorities in E7 apply active and sufficient policy collaboration to cushion the ecological impact of globalization. In order to produce a long-term and holistic structure for climate change policies, the negative ecological effects of globalization require lawmakers not to overlook the position it holds in environmental destruction especially in underdeveloped countries. Globalization is the creation of strategies in various fields involving policy, migration, finance, trade (import and export), and transport. If not properly monitored, globalization could promote trade in highly environmentally harmful technologies. Thus, in adopting ecological protection policies, these aspects of globalization must be taken into account. Globalization should be seen as a crucial economic instrument to boost ecological well-being in the long term.

The one-way causality between economic growth and emission suggests a potential weakness in the economic system of the investigated bloc. The implementation of E7 economies capital investment initiatives would decrease the strong dependency on natural resources that appear to encourage pollution in E7 economies. Renewable growth-driven opportunities and information enterprises must be given preference in E7 countries. To achieve green economy, there is need to encourage tax reductions, as well as lower interest rates, should be pursued in the energy mix in E7 economies, especially the participation of public private partnership involvement to foster green economy in the investigated bloc.

This study found that urbanization contributes greatly to E7 emission level. Thus, we propose that national decision-makers set up numerous environmental education projects in large cities. Furthermore, energy-efficient, electrical household equipment within the domestic segment must be encouraged. As urbanization encourages enhanced transportation needs, clever technology, as well as energy-efficient hybrid cars in city centers, must be encouraged to be used. Government officials should encourage urban people to embrace a healthy living that matches energy conservation, and use of the equipment from clean energy.

Finally, there are certain drawbacks to this study. The survey duration is over two decades. Certain pollution variables were not included either because of the data inaccessibility and limitations. It would be important to see if financial development could reduce the destructive environmental effects of the exploitation of natural resources. This is a hint for potential future studies to explore.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

The authors declare no conflict of interest

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Credit author statement

Stephen Taiwo ONIFADE: Conceptualization; Formal analysis; Methodology; Ilham HAOUAS: Validation; Visualization; Data curation; Bright Akwasi Gyamfi: Writing - original draft; Investigation, Festus Victor Bekun: Writing - original draft; Writing, Validation; Visualization; Supervision, and Corresponding.

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