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ARTICLE

Renewable energy, economic globalization and foreign direct investment linkage for sustainable development in the E7 economies: revisiting the pollution haven hypothesis

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Abstract

This present study is motivated by the United Nations Sustainable Development Goals (UN-SDGs) that concerns pertinent issues that comprises environmental sustainability (SDG-13), sustainable development (SGD-8), and responsible consumption (SDG-11), among others. To this end, this study examines the long-run and causality linkage between renewable and non-renewable energy, foreign direct investment, and economic globalisation in a carbon-income framework by use of both carbon dioxide emission and ecological footprint as a determinant for environmental degradation for E7 countries. Furthermore, a series of panel econometrics panel tests in conjunction with quantile regression is used to explore the relationship between the outlined variables for annual frequency data from 1990 to 2016. Empirical results trace a long-run equilibrium relationship among the highlighted variables as reported by Westerlund (2007). Additionally, this study gives credence and validates the pollution haven for the emerging (E7) countries examined, thus, implying the detrimental effect of foreign direct investment (FDI) on quality of environment in E7 economies. Interestingly, we observe that investment in renewable energy consumption will improve environmental quality. This outcome resonates with the advocacy of UN-SDGs-7, 11, 12, and 13, where emphasis is placed on responsible energy consumption (renewables), access to clean energy, and climate change mitigation. Conclusively, these revelations suggest the chase for adoption of low-carbon development technologies and strategies in E7 countries.

1 | INTRODUCTION

Inspired by economic globalisation as well as free trade, foreign direct investment (FDI) inflows to developing countries have grown exponentially over the last decades. However, according to the United Nations Conference on Trade and Development (UNCTAD, 2019), FDI to developing countries rose from 28.4 per cent in 1970 to 46.9 per cent in 2017 compared to the global FDI influx. Economic ideas such as the concept of the existence cycle (Vernon, 1966), the concept of globalisation (Buckely and Casson, 1976; Rafindadi and Ozturk, 2017), in addition to the concept of digital transformation (World Bank, 1993) allude to the motivation that FDI engenders economic growth, foreign exchange differences, mankind resources, as well as technical transition. For instance, FDI is commonly assumed to be one of the strategies to alleviate global tensions for increased energy consumption, as it facilitates digital transition between counties for environmental sustainability (Nathaniel *et al.*, 2020). Besides FDI motivation for direct and indirect linkage with economic growth, there are also questions about its environmental consequences. Scholars have theorised that in advanced countries, multinational companies (MNCs) often relocate "dirty" sectors to developing economics with much flexible environmental standards to maximise gain of the weaknesses/adversities of significant pollutant charges. This is called the "pollution haven hypothesis" (PHH). The PHH has inspired many studies, the early theory research concentrated on whether environmental control is key to FDI movements (Xie *et al.*, 2017; Ozturk and Acaravci, 2013). Over the years, these findings were dismissed as they did not explicitly describe the carbon emissions flow. As a result, recent studies have arisen to clarify the association between FDI influx and emission (see Solarin and Al-Mulali, 2018; Sarkodie and Strezov, 2019). The findings of extant literature have no consensus on the direction of connection between FDI and economic growth and key macroeconomic variables. This is alluded to as the econometric strategies employed and variables investigated.

On the premise of the above highlighted motivation, this study draws strength from the Environmental Kuznets Curve (EKC) concept and the United Nations Sustainability and Development Goals (UNSDGs) for sustainability. The UNSDGs focuses on pertinent issues of climate change action (SDG-13), responsible consumption (SDG-11), access to energy (SDG-7), and sustainable development (SDG-8), among others. The connection between these variables is intertwined. The focus on this study is on the emerging seven economies (E7). The E7 consists mainly of developing economies, which have not reached a substantial degree of industrial development (Gyamfi *et al.*, 2021b, 2021d; Bekun *et al.*, 2021a, 2021b, 2021c, 2021d). The developing economies are characterised for higher quest for economic growth path relative to the quality of the environment. This is known as the scale stage in environment literature (EKC). This creates an ideal for effective innovative distribution in terms of energy mix and interaction with rest of the world (globalisation). In this study, we explore the potential determinant of environmental degradation, which has been ignored in the extant literature. Previous literature identifies urbanization, industrialisation, anthropogenic activities, and energy consumption from fossil fuel base as determinant for environmental degradation (see Adedoyin *et al.*, 2021; Baloch *et al.*, 2021; Gyamfi *et al.*, 2021c). However, in this present study we extend the argument for the case of E7 economies by incorporating energy mix, FDI inflow, and economic interaction in terms of partnership that reflect SDG-17 as potential determinants for environmental degradation. The intuition for inclusion of globalisation stems from the fact that the world is connected in terms of trade and otherwise and FDI serves as key channel. To this end, this current study seeks to establish if FDI inflows can be correlated with environmental deterioration in the E7. A favourable association between FDI and environmental degradation presents the issue of whether E7 countries serve as emission shelters for MNCs. Alternatively, a negative relationship might suggest that FDI promotes sustainable development in technological innovation. The emphasis on the E7 is based on the principle of technological innovation theory, which implies that recipient states require a specific degree of growth to stimulate effective diffusion. Accordingly, advanced nations must have exceeded the threshold for efficient diffusion. However, less developed countries (LDCs) have not reached the stage where industrial development is required to draw adequate FDI to embolden technical dispersal (Cole and Elliott, 2005). Thus, the E7 countries are appropriate for this analysis since they operate among LDC range and emerging economics. As middle-income economies, most E7s witness fast growth and a huge chunk of worldwide energy demand. Their energy utilisation levels are a concern of FDI arrivals, which function as a stimulus for production, per capita income rise, and advances in total socioeconomic advancement as well as progress. Founded on the above, this analysis seeks to emphasise PHH. It utilises the E7 countries' cross-sectional data to answer the following hypotheses:

Hypothesis 1 (H_1): Does foreign direct investment mitigate ecological degradation in the E7?
Hypothesis 2 (H_2): Does green (renewable) energy usage in the E7 limit environmental degradation?
Hypothesis 3 (H_3): Does economic globalisation in the E7 enhance environmental damage?

In answering these hypotheses, the gaps this study seeks to unpin include: (i) this study uses dual benchmark indicators to evaluate environmental damage such as CO_2 emissions and ecological footprint (EFP). The mentioned indicators would serve as robustness and empirical correctness by which FDI influences the environment; (ii) the choice of the sampled blocs is strategic and tactical; E7 consists mainly of developing economies, which have not reached a substantial degree of industrial development. This creates an ideal for effective innovative distribution in terms of energy mix and interaction with rest of the world (globalisation); (iii) our study leverages on a carbon-income framework in conjunction with quantile regression to examine the impacts of FDI on the environment (De-Hart and Soule, 2000). The QR technique is appropriate for this analysis due to the existence of the impact of environment and FDI as a function of the "haven" or "halo" hypotheses. The econometric techniques of our study are robust and suitable for policy construction. The adopted techniques accommodate the probability distribution principle of linear regression and heterogeneous issues as outlined in the study of Graham *et al*. (2015). This analysis will be helpful for various means. Primarily, it will be applicable to scholars and analysts, since it will deepen their awareness of how PHH relates to emerging economies which have received less documentation in the extant literature. Moreover, this study will be helpful to E7 decision-makers in formulating strategies that can encourage or shield their economies from international funding depending on the essence of the interaction regarding FDIs and environmental degradation.

The remainder of this study is structured as follows: section 2 is a literature review, while section 3 focuses on methodology, model, and data incorporated in the study. Section 4 presents the findings. Finally, section 5 presents the conclusion and policy implications

2 | THEORETICAL MOTIVATION AND REVIEW OF RELATED LITERATURE

The primary hypothesis that explains the FDI–environmental degradation connection is PHH. The theory indicates that MNCs are required to move their large or polluted factories to nations with more tolerant ecological laws to escape paying regulatory enforcement fees in home countries (Zhang and Zhou, 2016). Copeland and Taylor (1994) suggest that desire to globally transfer pollutant emissions to developing nations derives from the desire to reduce economic and ecological costs in advanced nations. Simultaneously, developing countries are pressured to weaken each other by decreasing their ecological regulatory stringency to gain FDIs. These situations would culminate in a "dash to the bottom" among emerging nations with more flexible restrictions. This would contribute to a massive rise in emissions in communities that require tight sustainable development.

Grossman and Krueger (1991) outlined ways describing how FDI influences emissions including scale effect. When the influence of size and structure outweighs the impact of methodology, it infers the theory of emission refuge (PHH). The PHH converse is the emission halo theory, where the impact of method and structure overshadows the influence of size. The scale impact indicates that growing

FDI promotes economic development but has detrimental environmental consequences. The next concept is the composition impact, which stresses the direction by which FDI affects industry structure and allows the options of growing environmentally harmful or less environmentally damaging businesses. Grossman and Krueger (1991) suggest that this method may have favourable or unfavourable ecological consequences. The third process is the result of technique, indicating that FDI will contribute to technological changes that lessen emissions as well as beneficial fallout to local businesses.

When the influence of scale and composition outweighs the influence of the procedure, we point to it as emission haven. The PHH interaction is the emission halo theory, where the influence of method and structure overwhelms the influence of volume. Halo impact suggests FDI reduce ecological deterioration within the host nations. This is done by moving MNCs' greener technologies to emerging economies by FDI in accordance with innovation migration concept. One of the considerations for this is that MNCs can indicate unsustainable manufacturing methods, contributing to a long-term loss of popularity, prestige, and company.

2.1 | Empiric literature

Observational information on the FDI–environmental degradation nexus is increasing. Most studies displaying those nations with relaxed pollution controls draw FDIs suggesting PHH. From a different point of view, if these FDIs encourage the use of renewable technology to the degree that local companies attempt to duplicate this stainable technology, the effect would be the emission halo theory. Given the different mechanisms by which FDI could affect pollutant production, the interaction regarding the variables is not as simple. One explanation for this absence of clarification is the ecological pollution recognition issue. This research thus extends the concept of ecological pollution to involve carbon dioxide production and EFP. Research evidence will be examined under these concepts and restricted to very current analysis based on their fields of consensus and dispute.

2.2 | Economic growth, energy use, and environmental degradation

Several studies have been documented in the extant literature on the nexus between economic growth, energy consumption, and the environment. Alam *et al.* (2016) employed the autoregressive distributed lag (ARDL) limits test to examine linked time series data for the top CO_2 emission developing countries in both the short and long term, under both linear and non-linear assumptions. Carbon emissions grew statistically considerably in all four countries as income and energy use increased. While the association among carbon emission and population increase was found to be statistically significant in India and Brazil, it was shown to be statistically negligible in both the short and long run for China and Indonesia. Additionally, empirical evidence from the testing of the environmental Kuznets curve (EKC) hypothesis indicates that CO_2 emissions will drop over time as income increases in Brazil, China, and Indonesia. Thus, based on the EKC findings, it may be argued that these three countries should refrain from taking any actions or policies that would have a negative impact on their revenue in order to minimise CO_2 emissions. However, in the case of India, where CO_2 emissions and income are positively correlated, a rise in GDP over time will not result in a reduction in CO_2 emissions. Sharif *et al.* (2020) conducted a re-evaluation of the effect of renewable and non-renewable energy use on Turkey's ecological footprint. For the span 1965Q1–2017Q4, this study used a quantile autoregressive lagged (QARDL) technique. Additionally, we use Granger causality in quantiles to examine the causal relationship between the variables. The QARDL results indicate that the error correction parameter is statistically significant with the predicted negative sign for all quantiles, indicating the presence of a significant reverting to long-term equilibrium among the relevant variables and Turkey's ecological footprint. The findings indicated that renewable energy reduces the ecological footprint of each quantile in the long run. Nevertheless, economic expansion and non-renewable energy have a beneficial effect on the ecological footprint in the long to short run for all quantiles. Lastly, we examined the environmental Kuznets curve (EKC) hypothesis and found that the EKC exists in Turkey, as corroborated by QARDL data. Additionally, the outcomes of the causal study based on Granger causality in quantiles demonstrate the existence of a bidirectional causal association among renewable energy use, energy usage, and economic growth with an ecological imprint in the Turkish economy. More recently, a study by Gyamfi *et al*. (2020a) was motivated by the desire to examine the relationship between economic growth, pollutant emissions, and coal rent while accounting for the role of other covariates such as CO_2 damage and energy from nuclear energy sources, oil and gas energy, on an annual basis between 1990 and 2016. This study examines the coal rent–energy–environment nexus using panel ordinary least squares and panel quantile regression. The empirical evidence indicates that both real GDP and coal rent have a positive and considerable effect on carbon emission. More specifically, a percentage rise in GDP growth raises pollutant emissions by 0.400 per cent, and a percentage rise in coal usage reduces environmental protection by 0.088 per cent, as shown by the panel regression and confirmed by quantile regression projections at the data's various tails. Nonetheless, they observe that 0.95 per cent GDP growth significantly adds to environmental degradation, but renewable energy consumption at the median tail, i.e., 0.5 percentile, mitigates the negative effect of environmental deterioration. Furthermore, renewable energy was found to have a considerable negative effect on CO_2 emissions in the E7 countries, with a percentage increase in renewable energy consumption improving environmental quality by 0.588 per cent. Additionally, the predicted results imply that regulating coal usage by rent in addition to the cost of carbon damage will increase CO_2 emissions further in the E7 countries.

2.3 | FDI and CO2 emissions

Various studies affirm the PHH's presence (Solarin *et al*., 2017; Sun *et al*., 2017; Chang and Li, 2019). Nevertheless, while suggesting PHH, some of these experiments sought to find out mechanisms that could support these FDIs in an economically sustainable direction. These were mainly focused on other independent variables used in these experiments. Solarin *et al*. (2017) performed an analysis to confirm Ghana's PHH. They used the ARDL approach utilising data from 1980–2012 and proposed that effective organisation would help mitigate the detrimental environmental impact of FDI.

Abdouli and Hammami (2018) recognised the MENA countries' relationship regarding FDI, socioeconomic development, and ecological degradation. A GMM methodology was introduced to a dynamic concurrent data covariance matrix around 1990 and 2012. The analysis showed one-way relation that flowed from FDI inflows to CO_2 emissions; one of the conclusions was that developing countries should enforce ecological sustainability measures on FDIs which can enable nations to escape pollution haven traps. Analyses by the two mentioned studies indicate that developing nations should manage FDIs aimed specifically at technologically intensive, service-based, or ecologically responsible regions. Different from the findings outlined earlier, Chang and Li's report (2019) concentrated mostly on population levels in their analysis investigating the impact of FDI on CO_2 emission. Their research revealed where they aimed and showed that with growing FDI in the less densely crowded environment, CO_2 emissions declined substantially – their recommendation was that PHH can be best controlled in countries with limited populations. The only research which invalidates the haven impact theory is by Shao *et al*. (2019). This research attempted to evaluate PHH for two groups using the panel vector error correction model (VECM) and panel co-integration evaluation for BRICS and MINT nations. Analytical studies stretched from 1982 to 2014, and results confirm the presence of the halo impact theory on these groups; thus, the analysis recommends additional FDIs for these nations.

Additionally, Khan and Ozturk (2020) examined the causal relationship between environmental degradation as measured by carbon dioxide (CO_2) emissions and net foreign direct investment (FDI), as well as several other variables, including economic growth as measured by real per capita income and trade openness, using balanced annual data from 17 Asian countries from 1980 to 2014. Panel cointegration results validate the variables' long-run connection. Following a check for stationarity in the panel data, the panel fully modified ordinary least squares (FMOLS) approach was performed. The

FMOLS estimates for the CO_2 emission model indicates that inward FDI has a measurable positive effect on environmental pollution, corroborating the pollution haven hypothesis (PHH). Similarly, the outcomes of the FDI model show that CO_2 emissions are a form of environmental degradation, and that economic growth and trade openness are the primary variables of FDI. The findings from the panel causality analysis reveal bidirectional relationships between CO_2 emissions and inward FDI.

2.4 | Ecological footprint and FDI

Contrasting from CO_2 emission, the nexus involving FDI and ECF has been described by minimal academic literature. The majority endorse the PHH Solarin and AlMulali research (2018) developed to identify ECF above CO_2 emission as indicators for ecological deterioration. The findings show the presence of PHH (for unindustrialised nations) and halo-pollution (for industrialised nations) utilising CO_2 emission, in addition to ECF as ecological destruction variables.

Liu and Kim (2018) extensively analyse 44 Belt and Road (BRI)-affiliated nations. They used system PVAR with evidence from 1990 to 2016. Their study findings showed a two-way association between FDI and ECF. Moreover, Baloch *et al.* (2019) published a report on the impact of FDI for 59 nations on the ECF. The DKPR model was used for analysis and data from 1990 to 2016. FDI was utilised as an explanatory factor, showing that FDI induces ECF rises. The analysis recommended using carbon pricing for companies' dependent on old technologies or some sort of pollution manufacturing process. It also proposed supporting businesses fostering cleaner development.

Fakher (2019) analysed the ecological performance variables on ECF for OPEC nations, measured by the average Bayesian model and weighted least squares. This study data spans from 1996 to 2016. FDI was used as one of the response variables and results showed that FDI contributes to ecological deterioration. The analysis proposed that FDI could empower developing nations to prioritise environment-friendly innovations and industrialised emissions reduction. Sabir and Gorus (2019) examined South Asian nations' impact of globalisation and technical transition on the ECF. The research used the ARDL model panel. The outcome showed that FDI had a substantial impact on ECF and proposed turning to clean energy options to minimise ecological impacts and foster ecosystem protection. While several studies have shown the increasing growth of CO2 emissions in the extant literature hinged on the EKC theory. A large pool of literature exists with each providing no consensus on results. Our present study presents an extension of the EKC argument where we make the following contributions.

First, the present study incorporates energy use and globalisation and FDI that considers economic performance, to revisit the EKC phenomenon for E7 economies that have not been duly explored in the literature. The indicators in this study model are seemingly selected with motivation from the United Nations Sustainable Development Goals (SDGs) agenda to be achieved by 2030, which have received minimal documentation in most studies. Second, the study explores the effective combination of energy consumption, renewable energy consumption, FDI, globalisation, and economic growth, which serves as a dynamic effect for environmental quality. Third, the current study provides dual analysis with second general panel estimation techniques in conjunction with quantile regression which provides robust findings for stakeholder and policymakers for E7 economies.

3 | METHODOLOGY, DATA, AND MODEL CONSTRUCTION

3.1 | Theoretical background

The energy and environment literature has employed a variety of proxies and approaches to quantify environmental degradation. Danish and Baloch (2017), as well as Youssef *et al.* (2014), used sulfur dioxide (SO_2), but Cole *et al.* (1997), as well as Yahaya *et al.* (2016), used nitrous oxide (NO_2). In comparison, Arshad Ansari *et al*. (2020) determined ecological efficiency by using ecological footprint. Ahmad *et al*. (2016), Chen *et al*. (2020), Li *et al*. (2020), and Mrabet *et al*. (2017) used CO_2 emissions to quantify environmental deterioration, whereas Ahmed *et al*. (2020b, 2020a), Al-Mulali *et al*. (2015), and Dogan *et al*. (2020) used EFP as a proxy. Saleem and Shujah-ur-Rahman (2019) examined the effect of human capital on ecological sustainability and quantified ecological condition using EFP, CO_2 emissions, NO_2 emissions, and methane emissions (CH4) as indicators of environmental quality. They demonstrated, using dynamic, seemingly unrelated regression, that BC (human capital) strongly contributed to environment degradation and that energy use promoted EFP.

Altntaş and Kassouri (2020) evaluated environmental sustainability using EFP and CO_2 emissions in order to determine the utility of EFP as a method for ecological condition measurement. Sharif et al. (2020) asserted that RE enhances long-term environmental quality, while Alola *et al*. (2019) discovered that NRE degrades environmental protection. According to Tran *et al*. (2019) and Destek and Sinha (2020), RE decreased EFP while NRE degraded the ecosystem. According to Balsalobre-Lorente *et al*. (2018), NRs increase environmental quality. Danish *et al*. (2020) demonstrated that NR rent helps reduce the EFP, while Danish *et al*. (2019) demonstrated that it helps reduce CO_2 emissions. According to Hassan *et al*. (2019), NRs have a favourable link with environmental sustainability. Monfreda *et al*. (2004) established a relationship between lower per capita BC and increased POP. Begum *et al*. (2015) observed that while POPs have no significant effect on per capita CO_2 emissions, they anticipated that they may have a long-term negative effect on carbon emission in Malaysia. Numerous studies, such as those conducted by Dong *et al*. (2018), established a positive correlation between POPs and environmental degradation.

In summary, our study of the extant literature led us to believe that economic growth and its square, economic globalisation, renewable energy, and FDI all play a significant role in determining environmental quality. EFP is an aggregate and broader measure that we utilise as a dependent variable in this study with CO_2 emission as a proxy for environmental degradation in a separate model.

3.2 | Methodology

To identify the right analytical technique(s) to employ, the authors used the cross-section dependency (CD) test. The outcome from the CD test helps in either going for the first-generation or second-generation panel data econometric technique. The analysis will be biased, spurious, and inconsistent if CD test is not carried out (Dong *et al*., 2018; Nathaniel *et al*., 2020). To make sure these problems did not occur, the authors employed three CD tests which are the Pesaran (2007) CD test and the Pesaran (2015) scaled LM test for the sake of robustness check. More attention was placed on the Pesaran (2015) scaled LM test because of how our dataset is shown i.e., the time frame (T) figure is larger than that of the cross-sections (N) number. The CD test equation is shown in Eq. 1 as:

$$CD = \sqrt{\left(\frac{2T}{N(N-1)}\right)}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{p}_{ij}\right). \tag{1}$$

In equation (1), $\hat{p}_{ij}$ is the pairwise cross-sectional correlation coefficient of the residual from the ADF regression. T and N are the sample and panel scope separately for the cross-sectional as well as time period.

3.3 | Panel stationarity technique

The evidence of CD in the estimation brings out inefficiency in the first-generation stationarity technique (e.g., Im *et al*., 2003). Therefore, the authors employed a second-generation stationarity technique (CIPS) to solve the problem of inefficiency in the estimation. In a study by Pesaran (2007) on the CIPS stationary test estimation, the following cross-sectional augmented Dickey–Fuller (CADF) regression is expressed as follows:

$$\Delta Y_{it} = '_i + \rho_i^* Y_{i,t-1} + d_0 Y_{t-1} + \sum_{j=0}^{p} d_{ij} \Delta Y_{t-j} + \sum_{j=1}^{p} c_{ij} \Delta Y_{i,\,t-j} + \varepsilon_{it} \tag{2}$$

where Δ shows first differences, Y is analyzed variable, Y_t is the average at time t of all N observations, ε_{it} presents the error term. After running this CADF regression for each unit i in the panel, the CIPS statistics can be calculated by the following equation:

$$\text{CIPS} = \frac{1}{N} \sum_{i=1}^{N} CADF_i. \tag{3}$$

A second-generation cointegration test is performed in the proximity of first differences stationary variables, to assess the long-run effects of the variables under consideration.

3.4 | Panel cointegration estimation

The findings related to the Westerlund (2007) experiment to obtain proof of cointegration between the parameters. The error correction method (ECM) of the estimation is shown as:

$$\Delta Y_{it} = \delta_i' d_t + \phi_i Y_{it-1} + \lambda_i' X_{it-1} + \sum_{j=1}^{pi} \phi_{ij} \Delta Y_{\text{it}-\text{j}} + \sum_{j=0}^{pi} \gamma_{ij} \Delta X_{\text{it}-\text{j}} + \varepsilon_{it} \tag{4}$$

Thus, $\delta_t = (\delta_{i1}, \delta_{i2})$, dt $= (1, t)'$, and ϕ are the vector of parameters, deterministic mechanisms, as well as the error correction parameter, respectively. To identify cointegration existence, four tests were carried out. These four tests were built on the OLS technique of ϕi in Equation (3). Group mean statistics were made up of two out of the four estimations and are shown as:

$$G_\tau = \frac{1}{N} \sum_{i=1}^{N} \frac{\hat{\propto}_i}{SE\left(\hat{\propto}_i\right)} \tag{5}$$

$$G_\propto = \frac{1}{N} \sum_{i=1}^{N} \frac{T\hat{\propto}_i}{\hat{\propto}_i\,(1)} \tag{6}$$

Thus, $\hat{\propto}_i$ is denoted by $SE(\hat{\propto}_i)$ as the standard error. The semiparametric kernel technique of $\propto_i(1)$ is $\hat{\propto}_i(1)$. Two of the four remaining panel mean estimations are proof that the entire panel is cointegrated, and is shown as:

$$P_\tau = \frac{\hat{\propto}}{SE\left(\hat{\propto}\right)} \tag{7}$$

$$P_\propto = T\hat{\propto} \tag{8}$$

3.5 | Ordinary least square (OLS) and quantile regression (QR)

The analysis uses the technique for OLS and QR. The existence of cointegration assesses a long-term connection utilising the OLS econometrically rational. The present study applied the OLS with standard errors made by Driscoll and Kraay (1998). This method allows (1) heteroscedasticity, (2) serial correlation, and (3) cross-sectional dependency to be considered. Nevertheless, the QR is a statistical tool chosen based on its superior features to the OLS. The standard circulation as well as the zero-mean approval of the OLS error concept is rather unrealistic since there may be multiple distribution models for socioeconomic measures (De Silva *et al*., 2016). The QR covers this deficit (Salman *et al*., 2019; Nathaniel *et al*., 2020). The methodology (QR) does not presume the function of the period (Zhu *et al*., 2016a, 2016b). In the case of outliers (Bera *et al*., 2016), forecasts remain robust. No predictions for distribution (Sherwood and Wang, 2016) have been made. The technique for QR is shown as:

$$\mathrm{Quant}_{\theta}\left(\mathrm{yi}/\mathrm{xi}\right) = \mathrm{x}\beta_{\theta} + \mu_{\theta}, \tag{9}$$

where x is the exogenous variables, while y is the endogenous variables. The equilibrium place and disruption word of the explicit vector are θth and μ simultaneously. We use the contingent quantile regression that explores the effect of the regressors to be used in our econometric analysis on the foundation of the preliminary variable values. In the past, the QR technology was utilised in Hübler (2017), Xu and Lin (2018), Nathaniel *et al*. (2020), and other studies

GDP, GDP^2 EG, FDI, and REC denote economic growth, square of economic growth, economic globalisation, foreign direct investment, and renewable energy consumption, respectively. On the other hand, the present study adopts two environmental indicators (i.e., CO_2 emission and ecological footprint) for soundness of analysis. Furthermore, the use of CO_2 emission has been criticised in some of the extant literature. In recent times, the ecological footprint has gained more attention as proxy for environmental degradation given it covers a wider perspective of the environment. It is on this premise we adopted the use of both indicators for more robust analysis. To analyse the impact of GDP, EG, FDI, and REC at the designated quantile level, the authors formulated Equations (10) and (11), which are shown as:

$$\mathrm{Q}ø\left(\mathbf{LnCO_2}\right) = \vartheta ø + \xi_{1ø}\mathrm{LnGDP}_{it} + \xi_{2ø}\mathrm{LnGDP}^2_{\mathrm{it}} + \xi_{3ø}\mathrm{LnEG}_{\mathrm{it}} + \xi_{4ø}\mathrm{LnFDI}_{\mathrm{it}} + \xi_{5ø}\mathrm{LnREC}_{\mathrm{it}} \tag{10}$$

$$\mathrm{Q}ø(\mathbf{LnECF}) = \vartheta ø + \xi_{1ø}\mathrm{LnGDP}_{\mathrm{it}} + \xi_{2ø}\mathrm{LnGDP}^2_{\mathrm{it}} + \xi_{3ø}\mathrm{LnEG}_{\mathrm{it}} + \xi_{4ø}\mathrm{LnFDI}_{\mathrm{it}} + \xi_{5ø}\mathrm{LnREC}_{\mathrm{it}} \tag{11}$$

While the remaining variables maintain their original description, CO_2 and ECF represent CO_2 emission and total ecological footprint, respectively. For the explicative variables, the reference point is $\boldsymbol{\tau}$. Q$\boldsymbol{\tau}$ corresponds to the τth distributional point regression analysis that shall be determined utilising the method in Eqation (12):

$$Q_{\tau} = arg \min_{Q_{\tau}} \sum_{k=1}^{q} \sum_{t=1}^{T} \sum_{i=1}^{N} \left(\left|y_{it-}\alpha_{i-}x'_{it}Q_{\tau}\right| \omega_{it}\right) \tag{12}$$

Where q, T, N and ω_{it} stand for the number of quantiles, years, cross-sections, and weight of the ith country in the ith year respectively.

The E7 economics (Brazil, China, India, Indonesia, Russia, Mexico, and Turkey) were conceded by the authors for the study from the period of 1990 to 2016. The period of time for this analysis was based on availability of data. The time span was desperately dependent on data accessibility. Data on economic globalisation was obtained from KOF globalisation index (2020) and denoted as EG; ecological footprint was also obtained from Global footprint network (GFN, 2020) denoted as ECF.

On the other hand, data on CO_2 emission (denoted CO_2), economic growth (denoted as GDP), foreign direct investment (denoted as FDI), and renewable energy intake (denoted as REC) were obtained from World Development Indicators (WDI, 2020). See Table 1 for details on data, units of measurement, and sources.

4 | EMPIRICAL RESULTS INTERPRETATION AND DISCUSSION

From Table 2, which is a summary of statistics, the highest mean was economic growth with 8.4157, which shows the mean growth rate per year and the lowest mean was also obtained from foreign direct investment with 0.3855 indicating the mean investment per year. Again, the highest maximum was obtained again from economic growth, indicating that E7 economies grew at a maximum of 9.5513 per cent per year whilst the lowest was again foreign direct investment with the maximum investment into the E7 economy being 1.8224 per cent of their real GDP per annum. Moreover, from the median perspective, the highest is again economic growth, which indicates an annual growth of 8.8827 per cent, while the lowest again was foreign direct investment, showing 0.6646 per cent per annum of real GDP. Nevertheless, it was observed that the parameters are distributed in a skewed manner, and kurtosis values indicate that the distributions of six variables are further clustered, unlike confidence interval. The analyses of Jarque-Bera also deny the zero normality assumptions. The analysis also proves that CO_2 has a positive correlation with economic globalisation, foreign direct investment, and economic growth but is negatively correlated with renewable energy intake. On the other hand, there is a positive correlation between ecological footprint and economic globalisation and economic growth but there is a negative correlation between ecological footprint and renewable energy consumption.

The study proceeds to identify if there is cross-section evidence among the variable. The Pesaran (2007) CD test, Peasaran (2015) LM test, and the Breusch-Pagan (1980) LM test were employed. Table 2 indicates the CD in the frameworks. This proof allows the analysis to continue with rigorous estimation techniques for CD to avoid spurious inferences.

The stationarity results are shown in Table 3. The findings reported by Im *et al.*, 2003 indicated that all variables were stationary at first difference. An identical outcome was found in the second generation CIPS unit root test, which is vigorous to sequential association as well as CD test.

Table 4 displays the cointegration procedure for Westerlund (2007). The outcome proves that the variables of the two models are cointegrated. After establishing the presence of cointegration, we advanced with the two regression analyses. Our review will, however, be focused on the QR evaluation with little comparison with OLS. (Table 5)

The output of quantile regression is of two groups (based on the two indicators considered measurements of environment), output based on carbon emission, and the output based on ecological footprint as reported in Table 6. For the output of carbon (CO_2) emission, significant positive and negative relationship is established between economic growth and CO_2 across the quantiles for cases of economic growth (i.e., GDP per capita and squared GDP per capita). This confirmed EKC hypothesis with inverted U-shaped relationship between economic growth and carbon emission. This finding shows the pattern of relationship that exists between economic growth and carbon emission from the initial stage of economic development. This clearly showed the existence of environmental degradation across E7 countries at the initial stage of economic expansion because of economic activities in the countries targeting economic growth. In the initial period, degradation of the environment due to carbon emissions increased in the countries of our interest. Following the history of economic growth, the initial relationship that shows degradation of the environment was upturned indicating improvement on environmental quality of the selected countries. This same pattern is observed across the quantiles, and this finding is in line with the authors' expectation given that the countries involved are emerging countries who are at the frontline of economic growth. There is always a tendency that countries involved will put economic growth first, which comes with a cost of environmental damage. However, the opposite of this finding is revealed in the second model with ecological footprint as a measure of the

TABLE 1 Variables overview

Variables	Measurment	Sources	Symbols
CO_2 Emission	Metric tons per capita	World Development Indicators (WDI, 2020)	CO_2
GDP per Capita	In constant 2010 USD	World Development Indicators (WDI, 2020)	GDP
Foreign Direct Investment	% of real GDP	World Development Indicators (WDI, 2020)	FDI
Renewable Energy Consumption	% of total final energy consumption	World Development Indicators (WDI, 2020)	REC
Economic Globalization	KOF globalization Index	(Gygli et al., 2020) https://kof.ethz.ch/en/forecasts-and-indicators/indicators/kof-globalisation-index.htm	EG
Ecological Footprint	Global hectares per capita	GFN (2020)	ECF

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

TABLE 2 Summary statistics and correction analysis

	LnCO2	LnECF	LnEG	LnFDI	LnGDP	LnREC
Mean	1.0838	0.6866	3.7146	0.3855	8.4157	2.9947
Median	1.0137	0.7892	3.8462	0.6646	8.8827	3.1991
Maximum	2.6376	1.9314	4.7057	1.8224	9.5513	4.0716
Minimum	−0.3439	−0.2445	2.7188	−3.6036	6.3552	1.1718
Std. Dev.	0.7779	0.6077	0.3955	0.9466	0.9158	0.9075
Skewness	0.3047	0.0568	-0.6840	−1.1792	−0.7637	−0.6955
Kurtosis	2.2733	1.7945	2.8235	4.5623	2.2085	2.2720
Jarque-Bera	7.0836	11.547	14.982	63.025	23.308	19.409
Probability	0.0290	0.0031	0.0006	0.0000	0.0000	0.0000
Sum	204.83	129.76	702.05	72.855	1590.56	566.00
Sum Sq. Dev.	113.76	69.438	29.415	168.46	157.66	154.82
Observations	189	189	189	189	189	189
	$LnCO_2$	**LnECF**	**LnEG**	**LnFDI**	**LnGDP**	**LnREC**
$LnCO_2$	1.0000					
p-value	——					
LnECF	0.9204*	1.0000				
p-value	(0.0000)	——				
LnEG	0.5290*	0.5170*	1.0000			
p-value	(0.0000)	(0.0000)	——			
LnFDI	0.2182*	0.1052	0.2381*	1.0000		
p-value	(0.0026)	(0.1496)	(0.0010)	——		
LnGDP	0.6333*	0.5379*	0.7046*	0.2072*	1.0000	
p-value	(0.0000)	(0.0000)	(0.0000)	(0.0042)	——	
LnREC	−0.9531*	−0.9325*	−0.4804*	−0.1036	−0.5609*	1.0000
p-value	(0.0000)	(0.0000)	(0.0000)	(0.1560)	(0.0000)	——

Source: Author's computations: Note: *, ** and *** are 1%, 5% and 10% significant level respectively.

TABLE 3 Cross-sectional dependency (CD) test results

	Pesaran (2007) CD Test	Pesaran (2015) LM Test	Breusch-Pagan LM Test
$LnCO_2$ = f(LnEG, LnFDI, LnGDP, LnREC)	0.588	3.149*	1794.52*
LnECF = f(LnEG, LnFDI, LnGDP, LnREC)	−2.444**	2.442**	2090.91*

Note: *, ** and *** are 1%, 5% and 10% significant level respectively.

environment. Also, another difference between the findings from the two models with regards to economic growth is scale of the coefficients. Reason for this, could be from the composition of the indicators (CO_2 and ECF). It is confirmed that CO_2 is just a part in the composition of EFC and GHG with about 72 per cent of emissions in greenhouse gases (Udemba, 2021). In fact, these findings will aid policymakers in the selected countries to pay attention to the economic operations for effective management of the relationship between economic development and environment development to avoid huge trade-off between economic development and the environment. Comparing findings according to OLS in the two models shows that findings of OLS established the same relationship between economic growth and the environment for the two models there by confirming EKC for the case of

TABLE 4 Panel IPS and CIPS stationary estimation

	IPS				CIPS			
	Intercept		Intercept & trend		Intercept		Intercept & trend	
Variables	Levels	1st Diff	Levels	1st Diff	Levels	1st Diff	Levels	1st Diff
$LnCO_2$	−0.4138	−4.8530*	−4.8530	−4.8090*	−2.367**	−4.205*	−2.478	−4.231*
LnECF	−0.4858	−4.9637*	−2.6511	−4.9010*	−2.694	−4.713*	−2.736***	−4.769*
LnGDP	−0.1601	−3.7656*	−2.0320	−3.8771	−1.753	−3.041*	−1.345	−3.323*
LnEG	−2.3024	−5.0154*	−2.0959	−5.2420*	−2.334	−4.362*	−2.357	−4.651*
LnFDI	−2.6168	−5.5667*	−2.1042	−5.8441*	−2.241	−4.516*	−1.860	−5.232*
LnREC	−0.5928	−5.0343*	−2.6322	−4.9584*	−2.657	−4.672*	−2.657	−4.794*

Note: *, ** and *** are 1%, 5% and 10% significant level respectively.

TABLE 5 Westerlund (2007) cointegration estimation

	Group statistics		Panel statistics	
Model/dependent	$G\tau$	$G\alpha$	$P\tau$	$P\alpha$
$LnCO_2$ = f (LnGDP, LnEG, LnFDI, LnREC)	−1.120*	−4.380*	−4.198**	−3.801*
LnECF = f (LnGDP, LnEG, LnFDI, LnREC)	−0.807*	−3.164*	−1.225*	−2.656**

Note: *, ** and *** are 1%, 5% and 10% significant level respectively.

TABLE 6 Ordinary Least Square (OLS) and Quantile Regression (QR) Result for long run relationship

	OLS	Q.10	Q.25	Q.50	Q.75	Q.90
Dependent variable: $LnCO_2$						
LnGDP	0.9113*	0.76462*	0.8138*	0.8501*	0.2384**	0.0467*
$LnGDP^2$	−4.0900*	−7.92e-0*	−5.53e-0**	−3.49e-0**	−6.47e-0*	−1.07e-0*
LnEG	0.0178**	0.54681*	0.1910**	1.0133*	0.3934*	0.3024**
LnFDI	0.0079***	0.0098	0.0289***	0.1111*	0.3286*	0.2934*
LnREC	−0.4911*	−0.4292*	0.4793*	−0.5374*	−0.8415*	−0.9542*
Constant	7.6021*	15.4073*	18.8748*	22.5318*	14.8769*	12.4916*
R2/Pesudo R2	0.4008	0.2693	0.2062	0.3736	0.3680	0.4786
Adj R-square	0.6929					
Observation	189	189	189	189	189	189
Dependent variable: LnECF						
LnGDP	−0.0205***	−0.0811**	−0.0937**	−0.0459**	−0.0198**	−0.0118**
$LnGDP^2$	2.88e-*	2.44e-0	3.97e-0*	3.25e-0*	2.55e-0*	1.58e-0*
LnEG	0.1642*	0.0352**	0.3168*	0.1876*	0.0169*	0.0514**
LnFDI	0.0026*	0.0214***	0.0103**	0.0013**	0.0168***	0.0123**
LnREC	−0.6488*	−0.6592*	−0.6501*	−0.6185*	−0.5914*	−0.6227*
Constant	2.0050*	2.8869*	1.9075*	2.0356*	2.6213*	2.9831*
R2/Pesudo R2	0.9743	0.9025	0.8721	0.8385	0.8362	0.8362
Adj R-square	0.9737					
Observation	189	189	189	189	189	189

Note: *, ** and *** are 1%, 5% and 10% significant level respectively.

CO_2 and non-existence of EKC for the case of ecological footprint. This supports the notion that emerging countries are economically progressing at the expense of their ecological performance. The outcome is in agreement with the findings by Charfeddine (2017), Omri *et al*. (2015), and Galli (2015). For the interaction between economic globalisation and environment degradation, positive and significant relationships exit across the quantiles in both models (CO_2 and EFC). For the model with CO_2 as the dependent variable, all the quantiles display positive and significant relationships between economic globalisation and the environment, while a positive association exists among economic globalisation and ecological footprint as well for the case of OLS. The same result is as well-established for the case of the model with ecological footprint across the quantiles. Again, positive and significant relationships exist between economic globalisation and environmental degradation for the case of OLS in model 2. This depicts significance of economic integration and globalisation in enhancing the poor quality of environment. This shows that opening up to the rest of the world has earned the emerging countries some level of environmental degradation. The rate at which some foreign investors from advanced countries penetrate emerging economies with carbon intensive economic activities shows the level of laxity on the environmental regulation that exists in some of the emerging countries. This tends to degrade the quality of the environment. This supports the findings from Udemba (2019) and, for China, Yang *et al*. (2019). We also found a positive relationship exists between FDI and CO_2 emission within all the quantiles. For the second model with ecological footprint, a positive relationship exists between foreign directive and all the quantiles. This confirms and supports the assertion made for economic globalisation. It shows that opening up of the emerging countries proves to be detrimental to the E7 countries. This shows that globalisation has drawn the attention of the foreign investors to the emerging countries who are likely to switch their productive activities with technologies structured to work with fossil fuels void of sustainable development. Even the OLS result from model 2 confirms the findings of quantiles with CO_2 and EFC in respect of FDI to the environment quality with positive relationship between FDI and ecology. This confirmed the expectation of existence of pollution haven hypothesis (PHH) and rejection of pollution halo hypothesis (PHH), and in agreement with the findings from Udemba *et al*. (2019) for China and Udemba (2020). The finding from both models confirmed a negative relationship between renewable energy consumption and environmental degradation. This is in line with the expectations of the authors, and it falls within the theoretical assertion which posits that renewable energy sources such as wind, solar, and hydro power tend to reduce high emissions and favour the environmental performance of countries. The outcomes of OLS in the two models are in support of the finding from the quantile results. This supports the findings by Bhattacharya *et al*. (2016) and Alola *et al*. (2019) for the case of European Union.

4.1 | Dumitrescu and Hurlin causality estimation

The Dumitrescu and Hurlin panel causality test is reported in Table 7. The panel causality test is necessitated by the need to assess the Granger non-causality moving from the explanatory variables to the explained variable as conceptualised in the study of Dumitrescu and Hurlin (2012) in an heterogeneous panel dataset. There are two different causality analyses in this estimation. The first causality test is CO_2 emission and the independent variables. It was observed that there is un-directional relationship between: economic globalisation and CO_2 emission, foreign direct investment and CO_2 emission, and economic growth and CO_2 emission. On the other hand, with the different dependent variables i.e., ecological footprint, it was observed that, there is a bidirectional relationship between ecological footprint and economic globalisation. Again, there is a unidirectional relationship between foreign direct investment and ecological footprint and economic growth and ecological footprint.

From the analysis, it is observed that economic globalisation has a strong effect on environmental degradation within the E7 countries. FDI and economic progress on the other hand also contribute to the environmental degradation within the region. In order to combat this pollutant, the policymaker can shift their attention to renewable energy since it is less of an emission pollutant, ensuring environmental sustainability within these countries.

TABLE 7 The DH Granger causality evidence_

Null Hypothesis	W-Stat.	Zbar-Stat.	P-value	Remarks
$LnCO_2$ = f(LnGDP, LnEG, LnFDI, LnREC)				
LnEG→$LnCO_2$	2.555	0.355	(0.7229)	Uni-directional
$LnCO_2$ →LnEG	4.862*	2.811	(0.0049)	
LnFDI→$LnCO_2$	3.076	0.909	(0.3632)	Uni-directional
$LnCO_2$→LnFDI	4.637**	2.572	(0.0101)	
LnGDP→$LnCO_2$	5.670*	3.672	(0.0002)	Uni-directional
$LnCO_2$→LnGDP	3.746	1.623	(0.1047)	
LnREC→$LnCO_2$	3.637	1.507	(0.1319)	No direction
$LnCO_2$→LnREC	2.821	0.637	(0.5238)	
LnECF = f(LnGDP, LnEG, LnFDI, LnREC)				
LnEG→LnECF	8.324*	6.497	(8.E-11)	Bi-directional
LnECF→LnEG	14.470*	13.042	(0.0000)	
LnFDI→LnECF	1.995	−0.242	(0.8087)	Uni-directional
LnECF→LnFDI	7.014*	5.103	(3.E-07)	
LnGDP→LnECF	9.828*	8.100	(4.E-16)	Uni-directional
LnECF→LnGDP	2.808	0.623	(0.5331)	
LnREC→LnECF	2.771	0.585	(0.5588)	No direction
LnECF→LnREC	2.225	0.003	(0.9978)	

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

5 | CONCLUSION AND POLICY RECOMMENDATION

Following the trends of global economic expansion and integration, which has drawn attention of the western (developed) world to developing economies and also triggered the necessity for globalisation and foreign direct investment, we found it interesting to study the effects of this trend on the environment for the seven selected countries. So far, scholars' views are divided with the supposed impact of globalisation and foreign direct investment on environmental performance and sustainable development of countries who opened up for economic integration. Bearing this in mind, the current study embarked on investigating the link and effects of globalisation and FDI on the environment. Two models with two different indicators are adopted in this study for a greater insight into our research. Different scientific approaches are equally employed for robust checking of the outcomes in this study. We hypothesised the expected outcome of this study in three ways: (1) FDI will mitigate environmental degradation; (2) green (renewable) energy usage will reduce environmental degradation; and (3) economic globalisation will reduce environmental degradation. Out of the many approaches we applied in this study, we draw our concluding remarks from the findings of quantile and OLS regression, and granger causality outputs.

Part of the results from both quantiles, OLS, and Granger causality affirm and support the authors' hypothesis, while other findings reject the authors hypotheses with respect to FDI and economic globalisation. Hence, the positive mitigation of environment with renewable energy consumption is affirmed with FDI and globalisation found aiding environmental degradation. Among the findings from quantile and OLS regressions are the positive relationship that existed between FDI and environmental degradation in both models, between economic globalisation and environment degradation, with a negative relationship observed between renewable energy consumption and environmental degradation. This shows the positive impact of renewable energy source on environment performance. Also, pollution haven hypothesis is confirmed in our finding with respect to interactions between

FDI, globalisation, and environment. Findings from Granger causality analysis attest to regression outputs. A causal relationship is established between economic globalisation and environmental degradation. Unidirectional transmission is seen passing from economic globalisation for the case of model 1, while bidirectional transmission is established between economic globalisation and ecology. Also, unidirectional causality is established between FDI and environment (passing from FDI to environment), between renewable energy sources and environment (passing from renewables to environment). Also, GDP is transmitting to the indicators measuring the environment in a unidirectional way. This is a pointer that economic growth is negatively impacting on the environment. The environmental degradation caused by economic growth could be stepped down by the mitigations from renewable energy consumption.

Due to the outputs being in line with the expectations of the authors, the policy recommendation is for the framing of policies that regulate liberalisation (FDI and globalisation) and limit the tendencies of exploiting the environment with dirty productive activities. Governments of the selected countries should keep an eye on the activities of the foreign investors and introduce policies both at private and public levels. Policies at private level could be placing a ceiling on the level of emission from each firm. Once any firm exceeds this level, it will pay some stipulated fine, and this will serve as a deterring factor from environmental degradation. From the public level, government authorities should come up with long-term policies and models that will sustain both economic and environmental performances. Provision of public transport services will limit the need for private automobiles. Creation of environmental protection ministries will enhance the quality of the environment.

Conclusively, the study leaves some gaps that could be investigated in future studies, especially with respect to sample period. Future research could apply an extended timeframe to test if the pattern of economic growth is impacting the environment in the seven countries. Furthermore, future studies could consider using disaggregated data and exploring the asymmetric nature of the outlined variables on the environment for other emerging and developing blocs to either refute or validate our findings. Additionally, apart from the seven selected countries, other emerging and developing countries could gain insight from this study when framing their sustainability visions for their respective countries.

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DECLARATIONS: AVAILABILITY OF DATA AND MATERIALS

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All authors accept the revision accordingly.

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Authors mentioned in the manuscript have agreed for authorship read and approved the manuscript, and given consent for submission and subsequent publication of the manuscript.

CONSENT TO PARTICIPATE

Note Applicable

CONSENT TO PUBLISH

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COMPETING INTERESTS

I wish to disclose here that there are no potential conflicts of interest at any level of this study.

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