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ORIGINAL ARTICLE

Carbon emission in MINT economies: The role of poverty, population, energy use and economic factors

Festus Victor Bekun[1,2,3] | **Gizem Uzuner**[4,5] | **Stephen Taiwo Onifade**[6] | **Andrew Adewale Alola**[7,8]

[1]Department of International Logistics and Transportation, Istanbul Gelisim University, Istanbul, Turkiye

[2]University of Economics and Human Sciences in Warsaw, Warsaw, Poland

[3]Research Center of Development Economics,, Azerbaijan State University of Economics (UNEC), Baku, Azerbaijan

[4]Department of Economics and Data Science,School of Humanities, Natural & Social Sciences, New Uzbekistan University, Tashkent, Uzbekistan

[5]Department of Finance and Economics, Faculty of Economics Administrative and Social Sciences, Istanbul Gelisim University, Istanbul, Turkiye

[6]School of Finance and Accounting, Economics Department, University of Vaasa, Vaasa, Finland

[7]CREDS-Centre for Research on Digitalization and Sustainability, Inland Norway University of Applied Sciences, Elverum, Norway

[8]Faculty of Economics, Administrative and Social Sciences, Nisantasi University, Istanbul, Turkiye

Correspondence
Andrew Adewale Alola, CREDS-Centre for Research on Digitalization and Sustainability, Inland Norway University of Applied Sciences, Elverum, Norway.
Email: andrew.alola@hotmail.com

Abstract
Poor environmental quality is usually observed in developing blocs. Some plausible explanations are due to the high poverty level and their economic characterisation. The present study focuses on exploring the effect of poverty on environmental degradation over annual data from 1990 to 2018 for MINT economies (Mexico, Indonesia, Nigeria, Turkiye). By leveraging panel econometrics procedures that are robust to cross-sectional and slope homogeneity issues, the results show evidence of an equilibrium relationship among the examined variables namely households final consumption expenditure, CO_2 emissions, GDP, electricity consumption and population over the sampled period. Findings from this study establish that poverty is a core to environmental degradation in Türkiye and the plausible explanation is due to the country's demography while on the contrary, Nigeria, Indonesia and Mexico show that poverty is not a core contributor to environmental degradation. Thus, from a policy lens, there is need for concerted efforts by government officials and all stakeholders in the examined countries to reduce environmental degradation by improving per capita income (SDG-8) in the region productive economic activities to raise income level in the bloc. Additionally, there is a need for energy transition from fossil fuel-based energy to cleaner energy alternative options. More policy caveats are elucidated in the concluding section.

1 | INTRODUCTION

Poverty eradication agenda lies at the bottom of economic policies among several nations across the globe, and it has even gained more prominence as the first on the list of Sustainable Development Goals (SDGs-1) for the 21st century by the United Nations (UN) (Dhahri & Omri, 2020; UN, 2022). While there may be a general perspective on the meaning of poverty, there are some levels of organisational or institutional variations in the definitions for the term within a certain scope (Atkinson, 1987; Lipton & Ravallion, 1995). Historically, poverty reduction campaigns have always coincided with economic growth stimulation agendas among nations. Aggressive economic strategies that are often designed by policymakers to tackle poverty and growth have been linked to poverty alleviation in many instances (Adogamhe, 2010; Michálek & Výbošťok, 2019; Suryahadi et al., 2012). In a related dimension, energy consumption alongside other related indicators that largely portrays environmental dimension has been linked with the aspects of poverty such as the human capital development (Akram et al., 2020; Dramani et al., 2024; Nadimi & Tokimatsu, 2018).

Although economic growth may yield desirable benefits like poverty eradication, unemployment reduction, improved health and education levels, however, it may also come as an opportunity cost in terms of the environmental quality levels among many nations. As the population widens, there is a higher tendency to exert more pressure on available scarce resources to support mass production activities to maintain the desired general welfare level of the public often set above the poverty line. Having foreseen some possible inherent challenges of rising demographic factors, Thomas Malthus as far back as 1798 argued that population will outstrip resources (Malthus et al., 1992; Xie, 2000). Fortunately, the theory appears to have failed after the Industrial Revolution of the 18th century as the world made significant economic progress via technology that brought in the era of mass production that enhanced overall consumption levels thus significantly reducing the poverty gap (Daemmrich, 2017). However, this development gradually ushered in another major threat to humanity as time went by. Sustaining the track of mass production to keep the growing population above the poverty line requires more resource utilisation that ultimately exposes the world to an imminent environmental crisis. Aggressive deforestation has led to the loss of several million square kilometres of forests, natural habitats and arable land (Humphreys, 2008), unrestrained solid minerals and other energy resources mining leading to land degradation, acute erosion, oil spillage and other diverse degrees of environmental pollution among other (Magris & Giarrizzo, 2020; Ukaogo et al., 2020). Eventually, the colossal effect of these developments has cut across every sphere of our lives ranging from increased health challenges from polluted air to increased environmental disasters involving loss of lives and properties from flooding, droughts and extreme temperatures (Dunlap & Jorgenson, 2012).

Historically, conventional energy sources like oil, coal and gas have helped us to meet up with the required amount of energy supply that is needed to keep global economic activities moving. Hence, the economic benefits of this increased energy production and consumption cannot be sidelined. For instance, it assisted in sustaining mass production which has improved the general welfare levels among the rapidly growing population in different developing countries. However, despite these benefits, in recent times, there have been growing environmental challenges of the increasing threats of accumulated greenhouse gas (GHG) emissions like carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) among others. These GHG have been historically attributed to the increase in conventional energy consumption (Heede, 2014), and this link has been confirmed in many countries including Nigeria (Ameyaw et al., 2019), Mexico (He et al., 2021), Indonesia (Rafindadi et al., 2014) and Turkey (Gokmenoglu & Sadeghieh, 2019).

Hence, the current study makes significant contributions to the literature in different regards. Firstly, it provides a robust analysis of the connections between poverty, population and economic growth and how these factors impact environmental quality. Thus, the conducted analysis essentially creates useful bases for stimulating targeted policies that are aimed at maintaining environmental sustainability in the long run. Secondly, in the extant literature, we observed that most studies have only focused on analysing the economic side of the environmental discussion (Alola & Onifade, 2022; Bekun et al., 2021), and many others have also focused solely on the population aspect (Balsalobre-Lorente et al., 2022; Erdoğan et al., 2021; Gyamfi et al., 2021; Kwakwa & Alhassan, 2018). Interestingly, the poverty facets have often been neglected, and to the best of the authors' knowledge, this study is the first to beam a searchlight on the poverty–environment dynamics for the MINT economies including Mexico, Indonesia, Nigeria and Turkey. Thirdly, the importance of understanding the poverty–environment dynamics cannot be overemphasised and the choice of the specific case of the MINT countries provides certain benefits that add to the merits of the present study. Notably, each of the countries has a sizable demographic representation in terms of population size that fits the scope of our research. For instance, Nigeria as the most populous African country is home to over 200 million people and has been characterised by growing campaigns against poverty coupled with the rising trends of environmental challenges despite its vast energy resources (Ay et al., 2020; Çevik et al., 2020; Hakan et al., 2022). According to a World Bank report, more than 40% of the population still live below the national poverty line in Nigeria (World Bank, 2023), and the poverty situation has been observed to remain unabated despite the significant economic growth that the country has witnessed in recent years (Dauda, 2017). However, the question of if and how the poverty situation influences the environmental quality level is still subject to research.

Furthermore, as seen in Figures 1 and 2, there has also been a significant growth in the population as well as energy consumption level among the three other countries in the MINT bloc. As of 2022, Indonesia, Mexico and Turkey have all witnessed substantial growth in energy use given their vast population of about 275.5 million, 127.5 million and 84.9 million people, respectively (World Development Indictors (WDI, 2022). It is difficult to have a single metric to compare poverty rates at national levels since the measurement standards are nationally determined and differ across countries. Nevertheless, unlike the Nigerian case, the other three countries—Turkey, Mexico and Indonesia on a general note, have made substantial progress in lifting their population out of the poverty line considering that the depth and incidence of poverty tend towards zero among these countries based on 2017 PPP poverty gap measure of $2.15 spending per day (WDI, 2022).

Meanwhile, available statistics show that all the countries in the MINT bloc have witnessed massive surges in carbon emissions in recent decades. For example, emissions in Indonesia have grown more than three times their amount in 1990 to approximately 573,197 CO_2 emissions (kt) in 2020 (WDI, 2022). A similar situation can also be observed in the case of Turkey where emissions in 2020 almost tripled the amount in 1990 reaching about 407,406 (kt) of CO_2 emissions (WDI, 2022). Therefore, the findings from the current study would be imperative for policy suggestions given that the MINT bloc is a group of rapidly emerging countries where authorities have vehemently laboured over the years to address poverty reduction among the teeming population while also having to contain matters of environmental degradations.

In addition, the adopted empirical procedure follows a rigorous methodology in analysing the available relevant data for the bloc between 1990 and 2018. We provide a literature review with a background theoretical framework from the EKC hypothesis in Section 2, while the method for the empirical analysis is outlined in Section 3. Finally, the result discussions were captured in Section 4, and the general summary and result-based recommendations were detailed in Section 5.

2 | LITERATURE REVIEW

2.1 | Theoretical framework

To keep the global population above the poverty line, sustaining economic growth is a key factor in enhancing the required income levels among nations. However, given the current increase in global environmental challenges, it is becoming increasingly important to scrutinise whether the strive against poverty vis-a-vis the aggressive moves to boost economic growth and income levels has any significant connection with environmental degradation levels among nations. This is part of the curiosity accounted for while probing the environmental impact of economic activities in the early work by Ehrlich and Holdren (1971), and thereafter statistically conceptualised (York et al., 2003). Additionally, environmental impact is also considered from other theoretical approaches including the environmental Kuznets curve

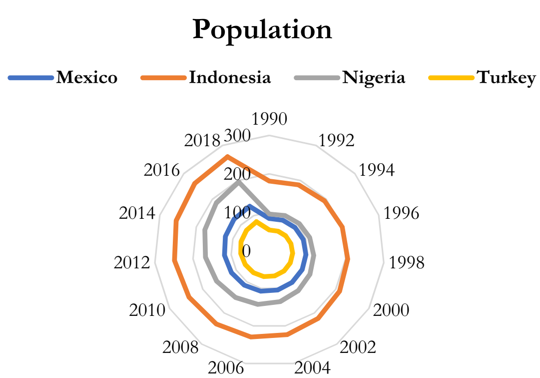

FIGURE 1 Growing population in MINT (Figures in millions of people). *Source*: Authors computation with (WDI, 2022) data for MINT countries.

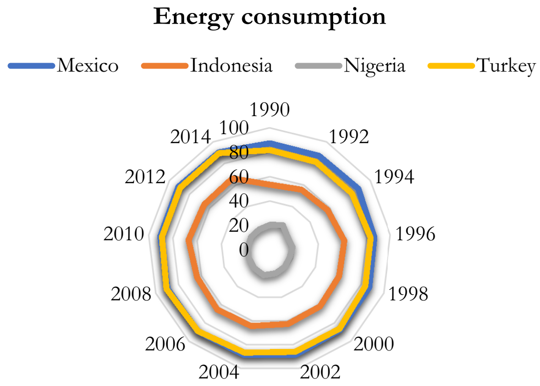

FIGURE 2 Fossil fuel energy consumption (% of total) in MINT. *Source*: Authors computation with (WDI, 2022) data for MINT countries.

(EKC) hypothesis (Kuznets, 2019). The EKC theory suggests that there will be an immediate threat to the environment at the initial growth level, but it further opines that such environmental threats will significantly subside at an advanced economic condition that ushers in higher levels of income among people in a given economy (Onifade, 2022; Shahbaz et al., 2019). Besides, there is still a noticeable gap to be filled as far as the poverty facets of the environmental discussion are concerned specifically in the MINT countries.

2.2 | Empirical literature

From the empirical literature, several related studies have addressed the poverty–emission nexus mainly in the Chinese economy, and a few others addressing the nexus using the example of the Indian and other economies (Baloch et al., 2020; Jin et al., 2018, 2020; Murthy et al., 1997; Ojha, 2009; Zhao et al., 2021). Murthy et al. (1997) set out to understand how poverty alleviation plans impact the levels of carbon emissions in India in their study covering a sample between 1990 and 2005. They discovered that a decrease in poverty level corresponds to a rise in carbon emission. Precisely, they discovered that the yearly rates at which emission levels rise in India have grown by about 1.1%. On the other hand, the study of Ojha (2009) on the Indian economy shows that it is carbon emission reduction programmes that increase the country's poverty level, thus arguing that increases in poverty level will be curtailed if there are considerable emission reduction plans. Therefore, going by the Indian case, the poverty–emission nexus is not clear-cut. The possibility that poverty rates influence emissions cannot be ruled out and the reverse can also be the case, thus opening the subject for more investigations.

Data between 2007 and 2014 were examined for the case of the Chinese economy within the poverty–emission context by Jin et al. (2018). They applied a simultaneous equations approach for the analysis in their study, and it was discovered that the average rise in the poverty level over the period coincides with the observed growth in carbon emissions level as well. In a more recent study on the Chinese economy by Jin et al. (2020), they provided evidence in support of the reduction in poverty level in China. Furthermore, while the evidence for poverty reduction stands out in China, they also discovered that while carbon emission has generally grown the economic growth follows the underlying EKC argument. Thus, they concluded that the links between the reduction in the level of poverty can be decoupled from the reduction in carbon emissions levels. On the other hand, Zhao et al. (2021) examined the poverty–emission nexus from the specific angle of the energy poverty level in China. They considered data between the years 2002 and 2017. Their results provide a relatively divergent view to those of Jin et al. (2020) showing that the rise in carbon emission cannot be separated from the poverty levels in terms of energy resources while identifying a causal nexus between poverty and emissions levels in the country.

Only a few cases of poverty–emission studies are available from other regions. Baloch et al. (2020) examined the poverty–emission nexus in Sub-Saharan Africa (SSA). They analysed a panel of about 40 SSA economies with the Driscoll Kray (DK) technique, and their study concluded that the level of poverty in those countries has triggered the rise in carbon emissions level. This level of poverty could be associated with the growing population and urbanisation in many countries. It is worth noting that while numerous studies have linked increased carbon emissions to several factors like growth and energy use in countries included in the MINT bloc either individually or wholly as a group (Balsalobre-Lorente et al., 2019; Bekun et al., 2022; Dogan et al., 2019; Odugbesan & Rjoub, 2020; Sunday Adebayo et al., 2022), little has been done on the aspect of poverty–emission nexus. Hence, the subject remained wide open for more empirical investigations. The results from this study are apt for policy suggestions given that the MINT bloc consists of fast-growing economies where the authorities need to be more committed to not only addressing economic challenges among the growing population alone but also ensuring that environmental quality level is not compromised.

3 | METHOD

3.1 | Data

The current study explored the nexus between the final consumption expenditure, CO_2 emissions, GDP, electricity consumption and population for MINT (Mexico, Indonesia, Nigeria, Turkiye). Due to availability of data on household expenditure, this study employs the Word Bank database for the related dataset over the period 1990–2018. The data for this study use Households and NPISHs final consumption expenditure (constant 2015 US$, name here as *Poverty*, that is low value of final consumption expenditure implies high propensity to be poor), CO_2 emissions (kt, name here as *CO2*), GDP (constant 2015 US$, name here as *RGDP*), electricity consumption (TWh, name here as *EC*) and population (total number of people, name here as *POP*) to model the poverty and environmental degradation nexus for MINT. The motivation for this study stem from the United Nations Sustainable Development Goals (UNSDG's-2, 8, 12 and 13) that highlights poverty reduction or zero poverty (SDG-2) with a decent work environment (SDG-8) while having responsible production and consumption (SDG-12) without compromise for environment (SDG-13). The current study builds on the study of (Masron & Subramaniam, 2019; Shah et al., 2022) that outlines the increasing role of household consumption, rising population and energy consumption on environmental quality. The economic model of the stated study is as follows:

$$CO_2 = f \text{ (poverty, real GDP, electricity consumption, population).}$$

3.2 | Empirical analysis

Before starting to examine the relationship between the variables of interest, there is a need for some preliminary analysis such as cross-sectional dependency (CD) and homogeneity tests to choose the most appropriate econometric approaches. The first step is to check cross-sectional dependency among the selected panel bloc given potential integration arising from globalisation, international trade and financial integration. If the presence of cross- sectional dependency is ignored, panel data efficiency may be significantly reduced (Phillips & Sul, 2003). Thus, it is crucial to take into account this issue in order to obtain robust coefficient estimates. For the purpose of checking cross-sectional dependency within panel countries, we use the Pesaran (2004) CD test.

The second step is to use slope homogeneity test to check whether the data panel estimates account for country-specific or pooled across countries (Pesaran & Yamagata, 2008). Although there is an interaction between countries, it is unlikely that the assumption of slope coefficients being homogenous will hold because countries vary in their phases of development. Thus, it is important to check slope homogeneity for the panel data to avoid unreliable or misleading results. This study employs Swamy's test of slope homogeneity which is proposed by Swamy (1970). The null hypothesis of this test is, H_0: $\beta_i = \beta$ for all i, slope coefficients are homogenous across the countries.

Given the cross-sectional dependency, there is a need to use second-generation panel estimation techniques. Thus, we apply the Pesaran (2007) panel unit root test which is modified version of Im et al. (2003) unit root test to investigate the integrating properties of the variables under consideration. The CIPS (cross-sectionally augmented IPS) panel unit root test is particularly crucial in panel data analysis when addressing issues of cross-sectional dependency and heterogeneity among the units. The null hypothesis of the CIPS unit root test states that there is a unit root against the alternative hypothesis of stationary.

3.2.1 | Panel cointegration test and long-term coefficients analysis

In the current study, we use the LM bootstrap panel cointegration test which is proposed by Westerlund and Edgerton (2007) to investigate long-run relationship among the variables for the panel countries over the sample period.

The motivation of this selected technique is threefold: (i) It accounts for cross-sectional dependency in each country of the bloc; (ii) it allows for slope heterogeneity; and (iii) it provides robust results in small samples. All these features are in favour of our study. The null hypothesis of cointegration is tested against the alternative of no cointegration. This hypothesis can be tested by using the following test statistic:

$$LM_N^+ = \frac{1}{NT^2} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{w}_i^{-2} S_{it}^2, \tag{1}$$

where S_{it} is the partial sum of error terms in the estimated equation and $\hat{w}_i^{-2}$ is the variance of error terms in the long run.

If there is a cointegration relationship among the variables, then there is also need to estimate long-run coefficients of each independent variables in the equation. However, the presence of unit roots for the variables may lead to the ordinary least squares (OLS) estimators to be biased by the autocorrelation and endogeneity problem. To overcome this, we employ dynamic ordinary least squares (DOLS) method which is able to correct the possible biases by adopting parametric approach (Kao & Chiang, 2001). The DOLS technique expands the cointegration regression by augmenting lags and leads for independent variables to have orthogonalised residual terms. The DOLS equation applied in this study is as follows:

$$y_{it} = X_{it}'\beta + D_{1it}'\varphi_1 + \sum_{j=-q}^{r} \Delta X_{it+j}\delta + v_{it} \tag{2}$$

All long-run correlation between the residuals is eliminated by adding q lags and r leads of the each regressors.

4 | EMPIRICAL RESULTS AND DISCUSSION

Following the descriptive statistics in Table 1, which outline the basic summary statistics comprising measures of central tendency and dispersion of the variables under review. Subsequently, the correlation coefficient analysis result is presented in Table 2. The results of Table 2 outlines the Pearson coefficient correlation analysis, which highlights the one–one relationship between the variables under review. The first row indicates the correlation coefficient while second row renders their statistical rejection level of relationship in terms of probability. Furthermore, Table 2 indicates that the explanatory indicators are all positively associated with carbon emission with a strong significant level, that is probability value of less than 0.01%. The evidence suggesting the rejection of the cross-sectional dependence and slope homogeneity (see Table 3) are as well statistically significant, thus paving way for the relevant stationarity and coefficient estimation techniques. By deploying the Pesaran (2007) CIPS panel unit root test, the result shows that all the variables are stationary after first difference as displayed in Table 4. Consequently, the dynamic ordinary least square provides coefficient estimation for both the panel and time series accordingly.

Subsequently, the panel coefficient estimation is provided in the first part of Table 5. As revealed in the result, electricity consumption and economic growth are causing more environmental degradation through the outthrust of carbon dioxide. These results are expected because of the economic and energy profiles of the MINT countries. The MINT comprises of the developing economies which supposedly still relies on fossil fuels for economic activities, thus having high share of conventional energy in their respective total energy mix. On this path, and for the MINT countries, corresponding

TABLE 1 Descriptive statistics.

	CO_2	POVERTY	RGDP	EC	POP
Mean	272,302.5	3.74E+11	5.74E+11	119.1712	1.34E+08
Median	283,135	3.43E+11	4.89E+11	109.7	1.15E+08
Maximum	583,110	8.41E+11	1.26E+12	314.9	2.68E+08
Minimum	67,850	9.88E+10	1.51E+11	10.8	53,921,758
SD	143,597.7	1.86E+11	2.95E+11	86.14027	61,930,619
Skewness	0.12945	0.615992	0.446604	0.338361	0.625578
Kurtosis	1.743774	2.570369	2.155628	1.868117	2.144753
Observations	116	116	116	116	116

TABLE 2 Correlation analysis.

	CO_2	POVERTY	RGDP	EC	POP
CO_2	1.000				
	—				
POVERTY	0.830	1.000			
	15.878*	—			
RGDP	0.904	0.980	1.000		
	22.568*	52.887*	—		
EC	0.928	0.894	0.948	1.000	
	26.629*	21.287*	31.892*	—	
POP	0.230	−0.026	0.015	−0.056	1.000
	2.527**	−0.281	0.157	−0.595	—

Note: * and ** denote significance level at 1% and 5%. Furthermore, Row 1 indicates magnitude of coefficient between study variable while second row outlines their statistical rejection level in terms of probability.

TABLE 3 Cross-section dependence and slope homogeneity test results.

Cross-section dependence				
Variable	**CD test**	***p*-Value**	**Corr**	**Abs(corr)**
$\ln CO_2$	11.430*	0.000	0.866	0.866
lnPOVERTY	12.550*	0.000	0.951	0.951
lnRGDP	12.810*	0.000	0.971	0.971
lnEC	12.700*	0.000	0.963	0.963
lnPOP	13.180*	0.000	0.999	0.999
Slope homogeneity				
$\chi^2_{(15)}$				***p*-Value**
Swamy-S test 351.350*				0.000

*Significance level at 1%.

TABLE 4 CIPS Panel Unit root test results.

Variables	Level	*p*-Value	First difference	*p*-Value
$\ln CO_2$	−1.506	0.699	−3.339*	0.001
lnPOVERTY	0.441	0.670	−3.072*	0.000
lnRGDP	0.012	0.505	−4.603*	0.000
lnEC	−0.942	0.173	−2.977*	0.000
lnPOP	0.382	0.649	−2.477*	0.007

Note: * and ** denote significance level at 1% and 5%.

studies also aligned with the result that both energy and electricity consumption alongside economic growth spur environmental degradation (Agbede et al., 2021; Alola et al., 2022; Du et al., 2022; Odugbesan & Rjoub, 2020).

On the role of poverty (measured by the spending ability of households) and population, both show that environmental quality gets better in response to increase in population and the market value of all goods and services consumed by households including the non-profits institutions serving households. Intuitively, the result clearly reveals that improvement in poverty level of households incentives environmental quality possibly arising from the households' ability to consume environmentally friendly products. However, the role of population and poverty in environmental quality as documented in the literature remained inconclusive. Although there is reasonable evidence and economic intuition

TABLE 5 Panel cointegration and DOLS estimation test results.

(a) LM bootstrap panel cointegration	LM statistic	*p*-Value
Constant	1.428	0.914
Constant and Trend	5.071	0.447
(b) DOLS estimation	**Beta**	***t* Statistic**
Panel countries		
lnPOVERTY	−1.108*	−12.780
lnRGDP	1.010*	16.151
lnEC	0.8252*	8.096
lnPOP	−2.223*	−8.235
Mexico		
lnPOVERTY	−1.006*	−3.182
lnRGDP	1.597*	3.782
lnEC	0.989*	9.809
lnPOP	0.652	0.298
Indonesia		
lnPOVERTY	−2.618*	−19.613
lnRGDP	2.798*	23.040
lnEC	0.284**	2.319
lnPOP	−5.200*	−9.299
Nigeria		
lnPOVERTY	−0.971*	−3.431
lnRGDP	1.477*	7.046
lnEC	0.939**	2.596
lnPOP	−1.683*	−4.406
Turkey		
lnPOVERTY	0.163	0.662
lnRGDP	−1.833	−1.573
lnEC	1.089***	1.749
lnPOP	−2.662*	−3.064

Note: (a) *, ** and *** indicate the rejection of the null hypothesis at 1%, 5% and 10% significance levels, respectively. (b) $t_{0.01} = 2.61$, $t_{0.05} = 1.98$, $t_{0.10} = 1.65$.

to suggest that poverty is a significant causative factor on environmental degradation (Masron & Subramaniam, 2019), an earlier studies by Duraiappah (1998) and Ravnborg (2003) hinted that the nexus between poverty and environmental quality could reflect a complex perspective. For instance, by employing waste management practices as an environmental indicator for the case of the poor segment of Kuala Lumpur residents, Murad and Mustapha (2010) established that poverty does not cause environmental degradation among the examined group.

Meanwhile, the country-specific results largely align with the above panel revelation except in Turkey where the result indicates that poverty has no environmental consequence. For instance, the result shows that poverty remained a factor that propels environmental quality in Mexico, Indonesia and Nigeria. Noticeably, the impact of consumptions by households and non-profit institutions serving households appears to vary across these countries. Specifically, a 1% increase in expenditure capacity, that is less propensity to be poor is responsible for the decline in environmental degradation Indonesia, Mexico and Nigeria by ~2.6%, by ~1.0% and by ~0.97%, respectively. This observation could be explained along two assumptions: (i) environmental consciousness of these societies is driven by the peoples' spending capacity and the reverse is true given that their expenditures on good and services are dependent on spending capacity, and (ii) the main components of the goods and services that are consumed by these populations are also crucial to maintaining environmental quality.

Additionally, economic growth and electricity consumption are both seen to spur environmental degradation while causing more carbon emission in each of Mexico, Indonesia and Nigeria. Again, economic growth does not show any environmental effect in Turkey. While population increase also hampers environmental quality in the country. The role of economic growth on environmental degradation is also found to be more severe in Indonesia and followed by Mexico and Nigeria. This varying environmental effect across the above-mentioned three countries is expected given the variation in the volume of the countries' economic activities, suggesting that the Indonesia's higher GDP value is not without relatively high environmental drawback. Contrarily, a percent increase in electricity consumption is responsible for ~1.1%, ~0.99%, ~0.94% and ~0.28% increase in carbon dioxide emission in Turkey, Mexico, Nigeria and Indonesia, respectively. Apart from the confirmation of positive nexus between energy or electricity consumption and environmental degradation in panel analysis of the MINT countries (Adebayo et al., 2022; Kutlar et al., 2022), country-specific studies for these countries also largely align that conventional energy forms deteriorate environmental quality (Agboola et al., 2022; Koyuncu et al., 2021). Furthermore, Table 6 outlines the Dumitrescu and Hurlin (2012) causality analysis, indicating a one-way causality relationship between economic growth and carbon emission (CO_2 emission). The one-way causality runs from GDP to CO_2 emission. This corroborates the baseline regression that GDP in the economies drives environmental degradation. Thus, further affirms the dirty-growth hypothesis. Similarly, a uni-directional causality is observed running from poverty to CO_2 emission, while between energy and CO_2 emission a one-way causality is also observed. Interestingly a bi-directional causality is seen between population and CO_2 emission. This is, population growth in the MINT bloc drives CO_2 emission and vice-versa. These aforementioned results draw the conclusion that poverty, energy from fossil fuel-based sources and population growth drives environmental degradation which has its inherent economic and environmental consequences.

5 | DISCUSSION OF RESULTS

The present study has focused on the determinants of environmental degradation for the case of MINT economies. The current study focused on the pertinent role of poverty as measured by final household expenditure and other key macroeconomic indicators like energy consumption, real GDP and demographic indicator population growth. Empirical finding outlines an equilibrium relationship between the outlined variables. The established equalibrium relationship presents an interesting results for policy formulation. Globally, there has been a need to curb climate change issues, and the MINT bloc is no exception. The study results outlined the role of key macroeconomic indicators on environmental quality. From the extant literature, energy consumption especially from fossil fuel-based energy sources degrades the quality of the environment, which validates the energy-induced degradation hypothesis. Thus, we observed that in Mexico, Indonesia, Nigeria and Turkey, energy consumption dampens the quality of environment. The plausible explanation is due to the nature of the energy mix in MINT economies, where the core of her energy mix is from non-renewable energy sources. To this end, there is a need for a gradual diversification of the MINT energy mix to cleaner energy sources. Similarly, real economic growth also exhibits a similar trend to dampen environmental quality, thus validating the dirty-growth hypothesis where emphasis is on economic growth without emphasis on quality of the environment. This also stems from the need for industrialisation and modernisation, which motivate environmental degradation, as seen in our study baseline regression in Table 5. However,

TABLE 6 Dumitrescu-Hurlin Granger causality test results.

	W-Bar	Z-Bar	*p*-Value	Granger causality flow
$\ln GDP \neq> \ln CO_2$	3.668*	3.774	0.000	$\ln GDP \rightarrow \ln CO_2$
$\ln CO_2 \neq> \ln GDP$	0.498	−0.710	0.478	
$\ln POVERTY \neq> \ln CO_2$	3.007**	2.839	0.005	$\ln POVERTY \rightarrow \ln CO_2$
$\ln CO_2 \neq> \ln POVERTY$	0.232	−1.087	0.277	
$\ln EC \neq> \ln CO_2$	6.021**	7.101	0.000	$\ln EC \rightarrow \ln CO_2$
$\ln CO_2 \neq> \ln EC$	0.447	−0.782	0.434	
$\ln POP \neq> \ln CO_2$	5.798*	6.785	0.000	$\ln POP \leftrightarrow \ln CO_2$
$\ln CO_2 \neq> \ln POP$	3.055**	2.907	0.004	

Note: * and ** show the rejection of the null hypothesis at 1% and 5% significance level. ≠> represents 'does not Granger causality'.

interestingly, poverty as measured by household expenditure shows an inverse nexus with environmental degradation, which is against a priori expectation. The plausible explanation could be that the investigated MINT economies are mostly on a trajectory where income levels are low and at the same time at a transition level with insufficient income to industrialise and urbanise to increase pollution levels.

6 | CONCLUSION AND POLICY RECOMMENDATION

In the last decades, there been a global human demand for energy consumption which comes with it inherent consequences on environmental quality and sustainability. The environmental degradation stem from the anthropogenic activities of human mainly driven from consumption of energy from fossil fuel bases and countries per capital income level. Given this motivation, the consensus at the 26th United Nations Climate Change Conference (COP26) commits countries to limiting global temperature rise to 1.5°C by 2030. Thus, there is a dilemma between increase income level and quality of environment. To this end, there is need to examine within robust econometrics framework how poverty–energy dynamics plays on environmental quality in MINT economies. The present study leverages on panel econometrics estimators that circumvent for issues on cross-sectional and heterogeneity issues. According to the LM bootstrap panel cointegration test and DOLS long-run equilibrium relationship, there are interesting dynamics. Empirical results show that electricity consumption and economic growth are causing more environmental degradation through the outthrust of carbon dioxide. The plausible explanation is because most countries in MINT still rely on fossil fuels for her economic activities, thus having high share of conventional energy in their respective total energy mix. While on the other hand, poverty and population, both show that environmental quality gets better in response to increase in population and the market value of all goods and services consumed by households including the non-profits institutions serving households. From a policy lens, there are several implications from the poverty-carbon emissions nexus in the MINT countries. These policies ranges from

(a) Policy direction is required on the growth level, that is per capita income level of the countries examined, and the countries energy consumption (electricity consumption) mix damages her environmental quality. This revelation is instructive to government official in the countries. Thus, there is need for a paradigm shift in her energy portfolio from fossil fuel energy based to renewable energy sources. More precisely, there is need to transition from electricity generation plant that emits CO_2 to more renewable and clean sources of electricity in the region. However, these countries are plagued with low-income (GDP) level which makes this suggestion hard to attain. Thus, government official is enjoined to involve public-private partnership in her energy sector to make the energy transition. On the low-income level, there is need for more productive and engaging society to raise income level which will increase the purchasing power of her citizenry and by extension improve quality of the environment in MINT. This is possible as the citizenry can afford clean energy options with higher income level.

On the result with poverty and population, both show that environmental quality gets better in response to increase in population and the market value of all goods and services consumed by households including the non-profits institutions serving households. The plausible explanation to household income level is possible at a threshold that it cannot contribute to damaging the environment. The economics and intuition is that high income increase higher consumption propensity while in this case there is paucity of purchasing power (poverty). From another point of view, the inverse nexus between poverty measured by household final consumption and CO_2 emission is interesting. This highlights that poverty, that is a lower household income level, means reduced consumption due to a paucity of purchasing power, which results in decrease in environmental degradation. Developing economies, such as MINT, typically rely on a traditional and environmentally friendly approach, which stems from a decrease in industrialisation and urbanisation. This is because MINT's economy is still at the verge of reaching a steady economic state. Consequently, the panel baseline regression shows a reduction in environmental deterioration from poverty. Furthermore, relying on conservative sustainability initiatives promotes long-term sustainability. Conclusively, there is need for equilibrium on GDP and environmental indices to foster a balance ecosystem in developing economies such as the ones being examined.

(b) On the dynamics of population reducing environmental degradation is due to global awareness for clean and friendly ecosystem. Thus, the urbanisation or industrialisation of the examined countries notwithstanding, the awareness and education for cleaner environment is more eminent in current era.

6.1 | Limitations of study

The present study examined the impact of poverty on environmental quality in MINT economies while accounting for other key macroeconomic indicators like GDP, population and energy consumption. The present study is not devoid of limitations which future studies and researchers can undertake. These limitations range from use of households and NPISHs final consumption expenditure (constant 2015 US$) as proxy for poverty as against other measure such as poverty variable or multi-dimensional poverty measure. This is due to availability of the data for the MINT economies. Additionally, there is need to consider the role of renewable energy in the functional form to either refute or validate the mitigating effect of renewable to emission level as well established on the extant literature.

A striking finding from the present study is the fact poverty proxied by final household expenditure reduces CO_2 emission. This is not a priori expectation and serves as a major limitation, as the bulk of literature confirms that poverty exacerbates environmental degradation due to lack of purchasing power for alternative energy sources and innovative means that are more environmental friendly. Thus, plausible explanation were provided for the MINT economies, where income levels are low as the blocs are at transition level with insufficient income to industrialise and urbanise to increase pollution level.

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ORCID

Festus Victor Bekun https://orcid.org/0000-0003-4948-6905
Andrew Adewale Alola https://orcid.org/0000-0001-5355-3707

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