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Muhammad Tayyab Sohail,
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Near East University, Cyprus
Najia Saqib,
Prince Sultan University, Saudi Arabia

*CORRESPONDENCE
Mohamed F. El-Naggar,
mfelnaggar@yahoo.com

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RETRACTED: Do renewable energy consumption and financial development contribute to environmental quality in MINT nations? Implications for sustainable development

Tomiwa Sunday Adebayo[1], Mehmet Ağa[2], Ephraim Bonah Agyekum[3], Salah Kamel[4] and Mohamed F. El-Naggar[5,6]*

[1]Department of Business Administration, Faculty of Economics and Administrative Science, Cyprus International University, Nicosia, Turkey, [2]Department of Accounting and Finance Department, Faculty of Economics and Administrative Science, Cyprus International University, Nicosia, Turkey, [3]Department of Nuclear and Renewable Energy, Ural Federal University Named After the First President of Russia Boris Yeltsin, Yekaterinburg, Russia, [4]Department of Electrical Engineering, Faculty of Engineering, Aswan University, Aswan, Egypt, [5]Department of Electrical Engineering, College of Engineering, Prince Sattam Bin Abdulaziz University, Al-Kharj, Saudi Arabia, [6]Department of Electrical Power and Machines Engineering, Faculty of Engineering, Helwan University, Helwan, Egypt

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Maintaining a balance between the well-being of the economy and the environment has become a top priority for governments globally. In the contemporary age, world economies, particularly the emerging ones like MINT nations, highlight the need for eco-friendly economic expansion. The MINT nations are thriving economically but are having difficulty reducing their Ecological footprint (EF). This paper aimed to determine if factors such as population density, renewable energy, foreign direct investment, economic growth, and financial development impact ecological footprint in the MINT countries between 1990 and 2018. The study applied ample advanced econometrics such as method of moments quantile regression (MMQR), augmented mean group (AMG) and Common Correlated Effects Mean Group (CCEMG). The overall results indicated that the variables are integrated at the first difference and are cointegrated. The AMG, CCEMG and MMQR results reveal that economic growth deteriorates ecological well-being by promoting the EF while foreign direct investment, population density and renewable energy assists in enhancing it by mitigating the EF in the MINT nations. In addition, financial development does not exert a significant effect on EF. The Dumitrescu Hurlin Panel Causality results show unidirectional causality from economic growth, financial development, population density,

Abbreviations: AMG, Augmented Mean Group; CD, Cross sectional Dependence; CCEMG, Common Correlated Effects Mean Group; EF, Ecological Footprint; FD, Financial Development; EGR, Economic Growth; FDI, Foreign Direct Investment; PD, Population Density; R and D, Research and Development; SH, Slope Heterogeneity.

and renewable energy to EF. Based on these results policy recommendations are suggested.

KEYWORDS

population density, foreign direct, ecological footprint, renewable energy, sustainable development

1 Introduction

Unfortunately, no nation or region is exempt from the impacts of climate change as the globe has seen a tremendous rise in ecological problems. The recent COP26 in Glasgow has reaffirm the Paris accord with the main goal to secure global net zero by mid-century and keep a maximum of 1.5°C degrees of warming within reach. However, the recent Russia-Ukraine war has put several restrictions towards achieving this goal as several nations mostly in the European bloc are switching to nonrenewable energy to meet their energy demand. Unsustainable production and consumption practices are highlighted in several recent studies as one of the primary causes of climate change and ecological degradation (Shahbaz et al., 2018; Adebayo, 2022a; Samour et al., 2022b). In the context of emerging nations like MINT nations, which aim to make swift economic growth for the well-being of their population, unsustainable consumption and production are expected. Nevertheless, even affluent nations are experiencing ecological deficits as a result of increased resource demands and limited supply (Zhang et al., 2022)

Environmental degradation and climate change are becoming a problem in the MINT nations, which are emerging nations (Odugbesan and Rjoub, 2020; Sunday Adebayo et al., 2022). The MINT nations are experiencing ecological deficits due to escalating ecological strain brought on by rising demands for food, energy, water, and other resources as well as declining biocapacity. Considering that MINT nations are significant contributors to the growth of the global economy, it is crucial to evaluate the variables influencing their ecological sustainability. The BRICS economies—Brazil, Russia, India, China, and South Africa—are a formidable emerging economic bloc that has drawn significant attention from the world. However, (O'Neill, 2013), acknowledged other developing economies in 2013, such as Mexico, Indonesia, Nigeria, and Turkey (MINT). Moreover, (O'Neill, 2013), asserts that MINT nations, which collectively account for 1%–2% of global GDP, have a good chance of surpassing other nations' economies in terms of size and technological advancement in the years to come. MINT nations have implemented ecological policies and a variety of fossil fuel reduction strategies to address the issue of environmental deterioration (Odugbesan and Rjoub, 2020; Du et al., 2022). Additionally, these nations' ecological consciousness is growing due to the call for a green environment. However, after the COVID-19 outbreak, these countries spent billions of dollars on fossil fuels rather than clean energy, notwithstanding their intentions and commitments to a green environment (Sunday Adebayo et al., 2022).

This paper evaluates the role of renewable energy (RENC) and population density (PD) on the ecological footprint (EF) of MINT nations controlling foreign direct investment (FDI), financial development (FD), and economic growth (EGR). Energy is essential for a country's prosperity, yet using fossil fuels degrades ecological integrity through increasing carbon and EF (Acheampong, 2018). Countries might choose energy efficiency measures that could reduce energy use to minimize environmental harm, but these measures only have a limited positive impact. Moving toward alternate energy sources, including renewables, is the best course of action to address contamination of the environment and climate change. These environmentally friendly energy sources, including wind, solar, geothermal, hydropower, bioenergy, and others, can promote economic development and contribute to environmental preservation (Pata and Samour, 2022; Zhang et al., 2022). In order to facilitate the switch to green energy, nations must develop and execute thorough ecological legislation that curbs resource consumption and waste generation.

Conflicting results regarding the impact of financial development (FD) on environmental degradation and quality have been cited by several scholars (Shahbaz et al., 2018; Ahmad et al., 2022; Anwar et al., 2022; Samour et al., 2022a). The consequences of increased income, output and technological advancement might damage or enhance ecological quality due to financial development. A strong financial system will enhance credit availability by enabling households and businesses to expand their consumption, income, and production—factors that ultimately encourage growth. Consumers and businesses may invest in green energy, energy-intensive technologies and R&D thanks to the financial sector's increased availability of financing, which improves ecological quality (Destek and Sarkodie, 2019; Faisal et al., 2021; Samour et al., 2022b). On the flip side, weak financial sector development could enable fraudulent business activities that direct loans toward operations that are harmful to the environment (Shahbaz et al., 2016; Cetin et al., 2021). Additionally, having access to capital may encourage entrepreneurs to install new equipment and facilities, raising energy consumption and resulting in greater environmental pollution and waste discharges (Adebayo, 2022b). Moreover, FD, according to studies by (Al-mulali et al., 2015; Awosusi et al., 2022) and others, lowers ecological sustainability because it raises output and consumption levels, exacerbating energy use.

However, according to (Adebayo, 2022b), FD slows environmental deterioration by funding R&D and using greener, renewable energy sources. The contradictory findings in the research and the main conclusion that FD have a detrimental impact on environmental quality point to the need for absorbent factors that might balance the growing advantage of finance to ecological sustainability. To reap the benefits of economic growth for the environment, the domestic economy must exhibit specific attributes known as absorptive capabilities.

Foreign direct investment (FDI) influx has a favorable impact on the utilization of renewable energy and is a crucial tool for transferring contemporary technologies to developing nations. Moreover, it highlighted FDI as a key factor in disseminating technologies in emerging economies. Multinational firms, according to (Hanif et al., 2019; Xie et al., 2020), are better for the ecosystem than their domestic counterparts. As an illustration, (Eskeland and Harrison, 2003), discovered that American-owned facilities in emerging economies are more energy efficient because they use greener energy. This scenario is also known as the pollution halo hypothesis (PHH). FDI is a vehicle for improving local ecological standards through the transfer of greener technology and management methods, which also helps reduce non-renewable energy (Shahbaz et al., 2018; Samour et al., 2022a). On the contrary, the pollution haven hypothesis (PHH) contends that industrialized nations apply stricter environmental regulations than do emerging nations, which distorts current comparative advantage trends (Djellouli et al., 2022; Xu et al., 2022). As a result, the polluting companies relocate their activities from industrialized to emerging regions, turning the latter into “pollution havens.”

Against this background, this paper renders a three-fold contribution to the literature. Firstly, it evaluates the interrelationship between RENC and EF for MINT nations in the presence of PD, FD, EGR, and FDI. In the context of MINT nations, the authors were unable to identify any research paper on this interrelationship. Secondly, the research employed AMG and CCEMG methods with the method of moments quantile regression (MMQR), which considers endogeneity, autocorrelation and cross-sectional dependence. In addition, (Westerlund, 2008), cointegration and (Dumitrescu and Hurlin, 2012) techniques that address CD and other potential panel data problems were used. Third, the EF was used in the research as a proxy for ecological degradation. EF is unquestionably the most comprehensive environmental gauge for capturing anthropogenic pressure on water, soil, and air (Danish et al., 2019; Nathaniel et al., 2021). In order to obtain accurate results, this paper adopts an appropriate proxy for environmental degradation following contemporary literature.

The remaining sections are as follows: Section 2 offers an overview of the past studies. In Section 3, the procedures and theoretical background are presented. The analysis and suggested policies are presented in Sections 4, 5.

2 Literature review

This section presents findings of prior investigations on the nexus between population density, economic growth, renewable energy, FDI, financial development and ecological footprint. The association between income growth and environmental deterioration goes back to the study of (Grossman and Krueger, 1995). The result from this study demonstrated the increasing trend of income and ecological deterioration. Over the years, this fact, has been supported by several empirical investigations. For instance, the studies of (Balcilar et al., 2020; Ahmad et al., 2021; Rehman et al., 2021; Ali et al., 2022; Jahanger et al., 2022; Kartal, 2022; Kartal et al., 2022; Murshed et al., 2022) establish that economic growth is the main driver of ecological deterioration. This further reinforces the well-known environmental Kuznets curve (EKC) hypothesis. With the target of proposing a way towards achieving carbon neutrality for China, (Zhang et al., 2022), in their study using the nonlinear ARDL disclose that the real growth in China is a major stumbling block towards attaining sustainable development. The author further suggests that China needs to restructure its economic growth policies by considering the ecological quality. Likewise, the recent study on (Ibrahim et al., 2022) in Germany using the innovative wavelet and nonlinear ARDL reported that the main mitigation of ecological quality is EGR. The study further reinforces that Germany needs to impose a high tax on polluting industries. In the same vein, using data between 1990 and 2018 for the newly industrialized nations, the research of (Adebayo, 2022a) established the role of real growth towards an increase in ecological dilapidation. On the flip side, some studies affirm the positive effect of EGR on ecological sustainability. In summary, such studies advocate that economic expansion curbs ecological deterioration. For instance, (Usman et al., 2020), in their study in United States, affirmed EGR’s role in lessening ecological damage. A similar report is also deduced by the study of (Adebayo, 2022c) in Sweden.

Moreover, the effect of population density (PD) on ecological footprint is essential. Therefore, evaluating such an effect is vital. Furthermore, an increase in PD may be a compression in the overall land area and its marginal use, which might increase the EF. On the other hand, a larger PD could enhance the efficient utilization of a place’s natural resources, leading to a lower EF. Understanding whether the population is clustered in small or large cities, rural or urban regions, or areas with ample resources or few resources is vital in this regard since the impact of PD on EF might vary significantly based on these factors. Thus, it is clear that PD and EF nexus have produced mixed findings. For instance, (Zarco-Periñán et al., 2021), scrutinized the role of PD in the mitigation of ecological dilapidation. Population density is used in the research to determine how it affects emissions and energy use from buildings. The research was conducted on a per-person and per-household basis at the municipal level. The area that the city actually inhabited was taken into account. The suggested approach was used in the context of Spanish cities with a population of above 50,000. The findings indicate that energy usage per resident and household in dwellings increases with PD. Additionally, emissions rise in proportion to PD. The study of (Meng and Han, 2018) using data between 1989 and 2014 on the environment-population density nexus using multivariate Granger causality and Johansen cointegration tests reported that an increase in PD will lower CO_2 emissions per person. According to the research, attention should be paid to improving city tightness and population density *via* road building, particularly in new towns. In Bangladesh, the paper by (Kashem and Rahman, 2019) on the nexus between PD and ecological quality using ARDL and data from 1973 to 2014 documented that PD contributes to the ecosystem's detriment.

The association between renewable energy (RENC), financial development (FD) and ecological degradation has been conducted by numerous scholars; however, mixed results are documented. For example, the global data was used by (Kirikkaleli and Adebayo, 2021) to assess the nexus between FD, RENC and ecological quality using data between 1990 and 2015. The authors used DOLS and FMOLS to unearth this nexus. The result shows that both FD and RENC boost ecological sustainability of the global economy. Similarly, (Wu et al., 2022), using the wavelet tools inspected the joint effect of FD and RENC on the environment. The data spanning between 1980Q-2019Q4 documented that both FD and RENC contribute to lessening ecological deterioration at high and medium frequencies. Furthermore, when the effect of FD is considered, the negative effect of RENC on ecological deterioration intensifies. Likewise, using panel vector autoregressive (PVAR) analysis, (Charfeddine and Kahia, 2019), investigated the finance-renewable-environment nexus in 24 MENA nations between 1980 and 2015. Their findings indicate that FD and RENC have negligible impacts on economic growth and CO_2 emissions. These findings show that the MENA region's renewable energy and financial sectors need to do more to support economic progress and ecological quality improvements.

Several studies have been recorded regarding the association between FDI and ecological quality/degradation. The study of (Xie et al., 2020) on the connection between FDI and environment from 2005 to 2014 using a generalized panel smooth transition regression model in emerging countries documented that FDI can cause CO_2 levels to rise significantly. The findings of the economic growth's spillover impact, on the other hand, indicate that FDI could be able to lower CO_2 levels. Similarly, (Hanif et al., 2019), assessed the FDI-environment nexus. The study's findings showed that FDI accelerated ecological deterioration utilizing panel data covering 1990 to 2013. The empirical findings also show that FDI contributes to ecological deterioration and raises domestic carbon emissions, supporting the PHH. Moreover, (Shahbaz et al., 2019), explored the nexus between FDI and emissions in the MENA nations from 1990 to 2015 utilising the GMM method. The result from this study affirms the PHH, which indicates that FDI contributes to the deterioration of the ecosystem.

Based on the studies reviewed above, no studies are conducted on the MINT nations with a broad focus on sustainable development. The research done in this endeavor has shown disparate outcomes. Thus, they cannot provide a comprehensive picture of how to fulfill the SDG objectives. The current paper fills a research vacuum in terms of policy recommendations for MINT nations to achieve the SDGs' goals, while considering cleaner production techniques as the primary means of achieving these goals.

3 Data, theoretical framework, and methods

3.1 Data

In this current investigation, we evaluate the effect of population density and renewable energy on ecological footprint in the MINT nations. Other variables influencing ecological footprint such as financial development, foreign direct investment and economic growth are also considered in the model. The research data span between 1990 and 2018. The study period is limited by the inaccessibility of ecological footprint data beyond 2018. The economic model of the present investigation is based on the study of (Wu et al., 2022) by incorporating population density and financial development into the model. The economic function is depicted as follows:

$$EF_{it} = f\left(EGR_{it},\ RENC_{it},\ \ PD_{it},\ \ FDI_{it},\ \ FD_{it}\right) \quad (1)$$

In Eq. 1, ecological footprint, population density, economic growth, renewable energy, foreign direct investment, and financial development are denoted by EF, PD, EGR, RENC, FDI, and FD. The indicators are converted into natural logarithm forms to account for the growth impacts and avoid the problems with dynamic characteristics in series. The indicators used in this analysis are comprehensively presented in Table 1 with their measurement and sources. Furthermore, the box-plot in Figure 1 depicts the summary statistics of the variables.

3.2 Theoretical framework

This section presents the established association between ecological footprint and the regressors. The motive of most developing nations is to boost their economic growth. Most developing which the MINT nations also belong are pro-

TABLE 1 Data source and measurement.

Symbol	Name	Measurement	Source
EF	Ecological footprint	Global hectares per capita	GFN
PD	Population density	people per sq. Km of land area	WDI
RENC	Renewable energy consumption	% of total final energy consumption	WDI
EGR	Economic Growth	Per capita (Constant 2010 US dollars)	WDI
FDI	Foreign direct investment	FDI % of GDP	WDI
FD	Financial Development	Domestic credit provided by financial sector (% of GDP)	WDI

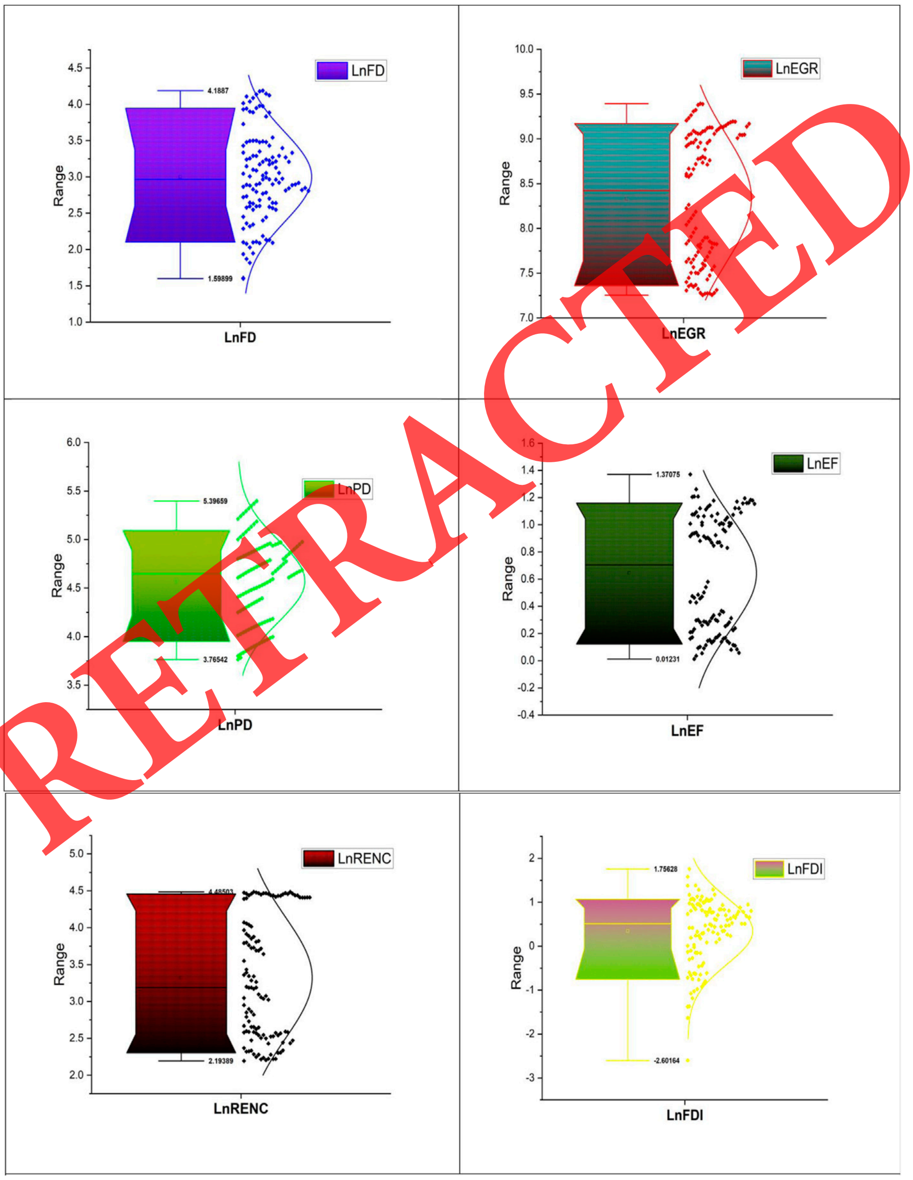

FIGURE 1
Box-plot of the variables of investigation.

growth in their plan. In a nutshell, they clamor for economic expansion by paying less attention to the environment (Acheampong, 2018; Shahbaz et al., 2018). They do this by utilizing energy-nonrenewable energy to carry out their economic operations. Since the energy used by these nations are fossil fuel based, it contributes to the ecosystem's contamination. Based on the abovementioned understanding, we anticipate economic growth to dampen the ecosystem by intensifying ecological footprint i.e., $\beta_1 = (\theta EF/\theta EGR > 0)$. In the recent COP26 in Glasgow, renewable energy consumption is identified as a major strategy for eliminating ecological deterioration. This idea is also validated by (Wu et al., 2022) and (Nathaniel et al., 2021) studies. According to them, RENC contributes to the lessening of EF. This is so because renewable sources of energy are eco-friendly and do not dampen the condition of the ecosystem. Therefore, the improving environmental effect of RENC is anticipated, i.e., $\beta_2 = (\theta EF/\theta RENC < 0)$.

Moreover, the impact of population density (PD) on ecological footprint is essential. Therefore, evaluating such an effect is vital. With increasing density, there may be a compression in the overall land area and its marginal use, which might increase the EF. On the other hand, a larger PD could enhance the efficient utilization of a place's natural resources, leading to a lower EF. Understanding whether the population is clustered in small or large cities, rural or urban regions, or areas with ample resources or few resources is vital in this regard since the impact of PD on EF might vary significantly based on these factors. Therefore, we anticipate PD to impact EF negatively if eco-friendly, i.e., $\beta_3 = (\theta EF/\theta PD < 0)$ or $\beta_3 = (\theta EF/\theta PD > 0)$ if it is not eco-friendly. Due to the apparent significant concentration of foreign investors (primarily from Asia), FDI is also highly strategically important in deciding the MINT nations' ecological management. The hegemony of FDI in the periphery of MINT nations results in a dual boom in energy (fossil fuels) consumption and exports, which impacts the MINT nations' EF. This reveals how FDI influences the environmental and economic performance of the MINT nation. It is thought that FDI promotes technological innovations and transfers, which may help reshape the energy industry to become less carbon-intensive and increase the availability of alternative sources of energy (Shahbaz et al., 2018; Samour et al., 2022a). For this reason, FDI is regarded as significant and identified as one of the elements in analyzing the MINT nations' environmental targets. Through its interaction with EF, FDI may have either a positive or negative effect on the ecological performance of the MINT nations, i.e., $\beta_4 = (\theta EF/\theta FDI > 0)$ or negative $\beta_4 = (\theta EF/\theta FDI < 0)$.

Numerous studies have been done on the interrelationship between FD and environmental deterioration. The emerging empirical evidence reveals two opposing views on how the two indicators will interact. While (Wu et al., 2022) indicates negative connection, studies like those by (Zhang et al., 2022) find a positive connection. Therefore, a positive association is expected if FD is eco-friendly, i.e., $\beta_5 = (\theta EF/\theta FD > 0)$ or $\beta_5 = (\theta EF/\theta FD > 0)$ if not eco-friendly. The theoretical framework above gives us insight into the economic model shown in Eq. 2 as follows:

$$EF_{i,t} = \beta_0 + \beta_1 EGR_{i,t} + \beta_2 RENC_{i,t} + \beta_3 PD_{i,t} + \beta_4 FDI_{i,t} + \beta_5 FD_{i,t} + \mu_{i,t} \quad (2)$$

Where; ecological footprint, population density, economic growth, renewable energy, foreign direct investment, and financial development are denoted by EF, PD, EGR, RENC, FDI, and FD. The coefficient elasticities are shown by $\beta_1 \ldots\ldots \beta_5$ and µ depict the error term. Subscripts t and I also represent time and nation.

3.3 Estimation procedures

This section provides the empirical methods applied in analysing the effect of the regressors (population density, economic growth, renewable energy, financial development and foreign direct investment) on ecological footprint in the MINT nations. The study highlights the empirical steps taken in this investigation as follows:

Firstly, the study conducted a slope heterogeneity test initiated by (Hashem Pesaran and Yamagata, 2008) and a cross-sectional dependence test. The SH test is carried out to identify whether the first or second-generation test will suit the panel analysis. Next, we evaluate the CD of the variables. The main problem with panel data analysis is the CD. It illustrates how unseen factors like residual interdependency, stock market index movements, economic shocks, and the volatility of other economic factors can impact observable factors. The disregard for CD might provide false results (Pesaran, 2015). The null hypothesis (Ho) provides evidence that CD does not exist in panel data.

Secondly, as soon as the parameters' integration orders are known, the cointegration test is used to assess the long-term relationships between the variables. The study uses the (Westerlund, 2008) 2nd generation panel cointegration test. This examination is more in-depth and extensive. In this test, the bootstrap panel Lagrange Multiplier is the fundamental cointegration method. The cointegration test's null hypothesis suggests that cointegration between variables is not present.

Third, we applied the augmented mean group (AMG) initiated by (Teal and Eberhardt, 2020) and cross-sectional mean group Correlated Effects Mean Group (CCEMG) initiated by (Pesaran, 2006) to evaluate the long-run association between ecological footprint and the regressors. Furthermore, the study employs the Method of Moments Quantile Regression (MMQR) initiated by (Machado and Santos Silva, 2019) with fixed effects for the extra robustness

TABLE 2 Slope heterogeneity test.

$\hat{\Delta}$	*p*-value	$\hat{\Delta}_{Adj}$	*p*-value
11.200*	0.000	12.830*	0.000

Note: 1% is depicted by *.

analysis. When the indicators have varying effects based on the conditional distribution of the dependent variable, quantile regression procedures are typically utilized. Since these studies primarily focus on the impact of the regressors on the conditional means of the EF, standard mean regression models like the OLS technique cannot demonstrate these diverse effects.

Lastly, the panel causality test suggested by (Dumitrescu and Hurlin, 2012), which considers CD and SH, was used to analyse the causal connection between the regressors and EF. The flow of the techniques, as mentioned above, is presented in Figure 2.

4 Findings and discussion

4.1 Pre-estimation results

The SH test, which relies on the modified delta and delta estimation, was used to examine the slope homogeneity. The findings are shown in Table 2. At a 1 percent level of significance, the null hypothesis is dismissed, indicating that slope heterogeneity exists among the MINT nations.

The CD test is a crucial evaluation in dynamic panel data. If the sections are interdependent, failing to account for their heterogeneity would lead to inaccurate estimation and reduced estimate effectiveness (Ozturk and Acaravci, 2016). The CD test's findings (Table 2) show that the null hypothesis is discarded at a 1% level of significance. Cross sections are dependent, and global shocks impact MINT nations members. These findings support the existence of a CSD problem in our data, which suggests that a significant shock, either favorable or unfavorable, to a specific variable in a single nation would impact the other nations in the panel. This result is anticipated since MINT countries probably have comparable structural, economic, cultural, and ecological traits. In light of the results of the CD test, the unit root, cointegration, and regression estimators that will be used in this research should consider the CD problem during the estimating stages.

The first-generation approaches, which presuppose CD, cannot be applied since there is confirmation of CD. Consequently, we used (Pesaran, 2007) CIPS and CADF panel unit root tests. The indicators (EF, EGR, PD, FD, and RENC) are nonstationary (see Table 3), as shown by the CADF unit root test at level. However, the series is discovered to be stationary after the first difference. The robustness of the CADF test is also

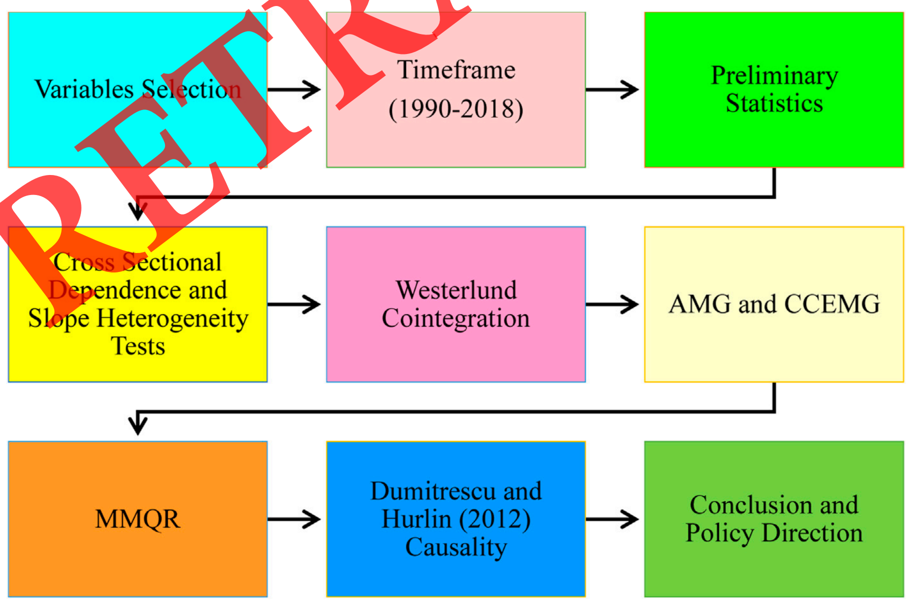

FIGURE 2
Flow of the analysis.

TABLE 3 CD and CIPS and CADF test outcomes.

	CD		CIPS outcomes		CADF outcomes	
	Pesaran CD	*p-value*	*I(0)*	*I(I)*	*I(0)*	*I(I)*
LnEF	8.048	0.000	−1.846	−5.043*	−2.442	−5.591*
LnEGR	12.15	0.000	−1.057	−4.036*	−1.872	−4.107*
LnRENC	9.846	0.000	−1.868	−5.222*	−1.292	−5.020*
LnFD	14.047	0.000	−1.4613	−4.394*	−1.703	−3.811*
LnPD	13.361	0.000	−1.712	−3.873*	−1.177	−3.246*
LnFDI	12.710	0.000	−2.037	−4.382*	−1.836	−4.243*

Note: *$p<1\%$.

TABLE 4 Westerlund cointegration.

Statistics	Value	Z-value	*p*-value
Gt	−2.956	−2.434	0.008
Ga	−9.198	−0.444	0.328
Pt	−4.776	−1.634	0.051
Pa	−7.993	−1.179	0.119

confirmed by the results of the CIPS test. In general, the results of the CADF and CIPS tests demonstrate that the series are integrated at first difference, supporting the employment of both the AMG and CCEMG estimators.

4.2 Cointegration result

The second-generation long-run cointegration test developed by (Westerlund, 2008) was used to confirm the long-term equilibrium connection between EF and the regressor. By adjusting for CD difficulties in the data, this approach, as opposed to first-generation versions, can predict the cointegrating features between EF and the regressors. The cointegration test outcome for the model is shown in Table 4. The outcomes show that there is an apparent connection between EF and PD, EGR, FD, RENC, and FDI in the MINT nations in the long-term. The statistical evidence suggests cointegrating in the model by rejecting the null hypothesis of no cointegration at 1%, 5%, and 10% statistical significance.

4.3 Long-run estimators (augmented mean group and Correlated effects mean group) results

This research used the AMG and CCEMG techniques to investigate the effect of PD, EGR, FDI, FD, and RENC on EF (see Table 5). The effect of EGR on EF is significantly positive, as shown by both AMG and CCEMG. The results show that 1percent upsurge in EGR caused 0.871% (AMG) and 0.787% (CCEMG) intensification in EF. These results affirm the damaging effect of EGR on the environment. Moreover, RENC effect on EF is negative, which is supported by both CCEM and AMG estimators. Thus, 0.314% (AMG) and 0.337% (CCEMG) decrease in EF is attributed to 1% upsurge in RENC. These results support the environmental improving effect of RENC.

The results from Table 5 also disclosed that the decrease in EF is attributed to the increase in FDI in the MINT nations. This infers that holding other indicators constant, 1percent upsurge in FDI caused a 0.018% (AMG) and 0.0237% (CCEMG) decrease in EF. Moreover, the result affirms the pollution halo hypothesis (PHH) in the MINT nations. The results also show that FD positively impacts EF, though the effect is insignificant. This shows that FD does not contribute to the MINT nations' increase/decrease in EF. Lastly, PD effect on EF is negative and significant as both AMG and CCEMG estimators recorded. The results disclose that 1percent upsurge in PD caused 2.558% (AMG) and 2.873% (CCEMG) reduction in EF.

4.4 Panel quantile outcomes

The current paper also used the MMQR to evaluate the effect of PD, FDI, RENC, EGR, and FD on EF in the MINT nations (See Table 6). The results obtained from Table 6 shows that in all the quantiles (0.1–0.90), positive effect of EGR on EF is evident across conditional distribution of EF. Furthermore, the strength of the coefficient increases as we move from lower to higher quantiles. The results suggest that EGR damage the ecosystem across all quantiles (0.1–0.90). The results from Table 6 also establish a negative RENC and EF nexus across all quantiles (0.1–0.90), with the strength of the coefficient diminishing as we move to the higher tails. These results are not surprising given the established emissions-reducing effect of RENC. Thus, RENC

TABLE 5 AMG and CCEMG results.

	AMG			CCEMG		
	Coefficients	z-statistics	*p*-value	Coefficients	z-statistics	*p*-value
LnEGR	0.871*	2.831	0.004	0.787*	3.723	0.000
LnRENC	−0.314*	−2.693	0.007	−0.337***	−1.955	0.059
LnFDI	−0.018*	−3.896	0.000	−0.023*	−3.061	0.000
LnFD	0.043	1.024	0.308	0.143	1.314	0.190
LnPD	−2.558*	−2.866	0.005	−2.873***	−1.828	0.069
C	1.583	0.522	0.606	1.686	1.453	0.147
RMSE	0.0264	0.0312				

Note: ***, ** and * denotes significance level of 10%, 5% and 1% respectively.

TABLE 6 MMQR results.

	Location	Scale	Low			Middle			High		
			0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.90
LnEGR	0.4188	0.0985	0.2443	0.2948	0.35526	0.4076	0.4442	0.4634	0.5020	0.5289	0.5687
	(7.76)*	(3.84)*	(2.57)*	(3.65)*	(5.18)*	(7.11)*	(8.36)*	(9.10)*	(9.79)*	(9.80)*	(8.36)*
LnRENC	−0.0769	−0.0503	−0.1661	−0.1403	−0.1094	−0.0826	−0.0640	−0.0542	−0.0349	−0.0207	−0.0004
	(−4.32)*	(3.31)**	(−4.61)*	(−4.345)*	(−3.93)*	(−3.76)*	(-3.45)*	(−3.09)*	(−2.72)**	(−2.35)**	(−2.01)**
LnFDI	−0.0326	0.3049	−0.0305	−0.0311	−0.0319	−0.0326	−0.0330	-0.0333	-0.0338	-0.0341	-0.03465
	(−1.95)*	(2.46)**	(−1.02)*	(−1.23)	(−1.57)	(−1.89)***	(−2.06)**	(−2.11)**	(−2.09)**	(−2.00)**	(−1.80)**
LnFD	0.0211	1.4216	0.0720	0.0572	0.0396	0.0243	0.013	0.0081	−0.0031	−0.0109	−0.0225
	(1.09)	(1.24)	(1.61)	(1.59)	(1.28)	(1.15)	(0.70)	(0.43)	(−0.16)	(−0.54)	(−0.92)
LnPD	−0.3083	−0.0172	−0.1635	−0.1547	−0.1441	−0.1350	−0.1286	-0.1252	−0.1185	−0.1137	−0.1068
	(3.04)*	−2.56)**	(2.00)**	(−2.24)**	(−2.58)*	(-2.86)*	(−2.93)*	(−2.91)*	(−2.69)*	(−2.44)**	−2.02)**
C	−2.0348	−2.5732	−0.4416	−0.9028	−1.454	−1.932	−2.2663	−2.441	−2.793	−3.0401	−3.402
	(−3.19)*	(−2.14)**	(−0.39)	(−0.94)	(−1.83)*	(−2.89)*	(−3.66)*	(−4.07)*	(−4.60)*	(−4.74)*	(−4.39)*

Note: ***, **, and * denotes 10%, 5% and 1% significance level. Values inside ( ) represents the Z-statistics.

decreases EF in each quantile. Moreover, the negative effect of FDI on EF is evident in each tail, affirming the PHH across all quantiles (0.1–0.90). Furthermore, the coefficient of FDI increases as we move towards the higher tails. Regarding the association between FD and EF, in each quantile, no evidence of a significant association between EF and FD. Lastly, the negative influence of PD on EF is documented in each quantile which shows that PD contributes to ecological quality across all the quantiles. Figure 3 presents the summary of the MMQR, CCEMG, and AMG results.

4.5 Dumitrescu hurlin panel causality results

The last empirical analysis is conducted to assess the causal connection between EF and PD, FDI, RENC, EGR, and FD (see Table 7). The results from the DH Panel Causality show no evidence of causality between FD and EF. Furthermore, unidirectional causality exists from FDI, EGR, FD, and PD to EF. These results show that RENC, FDI, EGR, and PD can forecast/predict EF in the MINT nations. Thus, when formulating policies on EF, the regressors (RENC, FDI, EGR, and PD) should be considered. These results are also documented by prior studies (Nathaniel et al., 2021; Beton Kalmaz and Awosusi, 2022; Ibrahim et al., 2022; Ojekemi et al., 2022; Zhang et al., 2022).

4.6 Discussion of findings

This section discusses the results of AMG, MMQR, CCEMG, and Dumitrescu Hurlin Panel causality estimators. The positive effect of economic growth (EGR) on EF is evident, suggesting that EGR boosts EF in the MINT nations. This result is expected given that most developing nations, such as the MINT nations

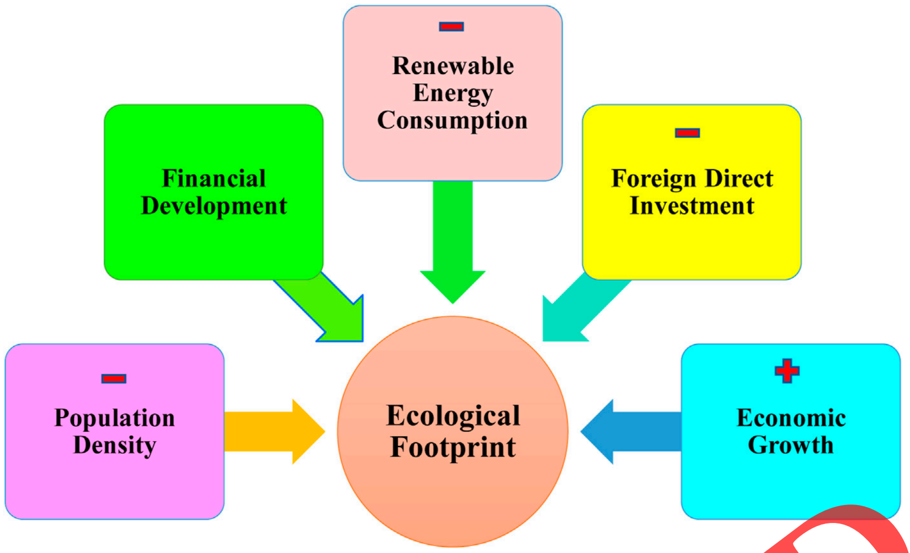

FIGURE 3
Summary of findings from AMG, CCEMG and MMQR.

TABLE 7 Dumitrescu hurlin panel causality tests.

Null hypothesis	W-stat	Zbar-stat	Prob
LnFD ≠ LnEF	2.3380	0.6120	0.7090
LnEF ≠ LnFD	2.1496	−0.0339	0.9729
LnFDI ≠ LnEF	4.2589	1.6790	0.0931
LnEF ≠ LnFDI	2.3772	0.1405	0.8882
LnEGR ≠ LnEF	8.0123	4.8313	0.0000
LnEF ≠ LnEGR	2.0079	−0.1514	0.8796
LnPD ≠ LnEF	7.1620	7.3200	0.0000
LnEF ≠ LnPD	3.5626	1.1386	0.2548
LnRENC ≠ LnEF	6.5472	6.9552	0.0000
LnEF ≠ LnRENC	2.5989	0.3389	0.7346

Note: ***, **, and * denotes 10%, 5% and 1% significance level.

aim to boost their economic growth while paying less attention to their ecosystem. In most developing such as the MINT nations, favor the pro-growth initiative. In a nutshell, these nations clamor for economic expansion by paying less attention to the environment. They do this by utilizing fossil fuel-based energy to carry out their economic operations. Since the energy used are fossil fuel based, it also contributes to the contaminant of the ecosystem. Similar outcomes are reported by the studies of (Hanif et al., 2019; Balcilar et al., 2020; Ali et al., 2021).

The study also affirms that renewable energy (RENC) impacts EF negatively. The significant role of renewable is vital towards a move to carbon neutrality, as stated at the COP26 meeting. These results show that establishing renewable energy projects in the MINT countries is crucial to contributing to a reduction in EF. We propose that considerable EF mitigation in the MINT nations may be achieved by extensive investment in current and future renewable energy projects and economic activity management. Several studies such as (Ibrahim et al., 2022), (Abbasi et al., 2022), and (Acheampong et al., 2019) documented similar results.

Moreover, the study finds a negative association between FDI and EF in the MINT nations. In order to assure low carbon emissions, (Shahbaz et al., 2018), suggested that FDI promotes flows of eco-friendly technologies and cutting-edge, creative manufacturing techniques across nations. This may be vindicated in the context of emerging nations because there is already a dearth of technology in these countries. As a result, FDI may allow for technological spillovers from advanced nations, which could raise the technological level of developing countries like the MINT nations and assist them in safeguarding their ecological resources. This result aligns with the studies of (Samour et al., 2022a) and (Shahbaz et al., 2018).

Moreover, the effect of population density (PD) on ecological footprint is negative. This shows that PD could enhance the efficient utilization of a place's natural resources, leading to a lower EF. Therefore, for the MINT nations, PD boosts ecological quality. This outcome corroborates the studies of (Meng and Han, 2018; Zarco-Periñán et al., 2021); however, it refutes the studies of (Gyamfi et al., 2022), who found that increasing PD may be a compression in the overall land area and its marginal use, which might increase the EF.

Lastly, an insignificant association exists between FD and EF in the MINT nations. According to (Zhang et al., 2021), the insignificant nexus between FD and EF is attributed to the fact the financial system of developing nations such as the MINT nations is at the initial phase. In this phase, FD is expected not to contribute to ecological sustainability/degradation. On the other hand, some studies found a negative association (Charfeddine and Kahia, 2019; Wu et al., 2022) and positive association between FD and EF (Cetin et al., 2021; Samour et al., 2022a).

5 Conclusion and policy implications

5.1 Conclusion

This paper evaluates the effects of population density, renewable energy, economic growth, financial development and foreign direct investment on ecological footprint in the MINT nations over the 1990–2018 periods. The study applied ample advanced econometrics such as method of moment quantile regression (MMQR), augmented mean group (AMG) and Correlated Effects Mean Group (CCEMG). The overall results indicated that the variables are integrated at first difference and cointegrated The AMG, CCEMG, and MMQR results show that economic growth deteriorates ecological well-being by promoting the EF, while financial development, population density, and renewable energy assists in boosting it by mitigating the EF in the MINT nations. In addition, financial development does not exert a significant effect on EF. The results from the Dumitrescu Hurlin Panel Causality show no causality between financial development and EF. In contrast, unidirectional causality exists from economic growth, financial development, population density and renewable energy to EF. These results show that economic growth, financial development, population density and renewable energy can forecast/predict EF in the MINT nations.

5.2 Policy implications

The results of this research are thus of the utmost importance in ensuring that the MINT nations can fulfill their obligations to worldwide environmental development underneath the SDGs of the United Nations and Paris Climate Change Agreement. Even though the MINT nations might not have the necessary resources to uphold these obligations, this research is anticipated to serve as a guide for these nations in promoting adherence by supporting pertinent policy-making objectives. As a result, this research suggests the following policy implications to governments, policymakers, and stakeholders who are considering attaining environmental sustainability in MINT nations based on the results above. Firstly, an essential strategy for decreasing environmental deterioration is the employment of renewable energy sources rather than nonrenewable energy sources in economic sectors. Policymakers in the MINT nations may employ grants, subsidies, fiscal incentives and low-interest loans to boost renewable energy sources penetration to raise the renewable energy technologies affordability. To explicitly support renewable energy investment projects, the governments may establish regional or global green energy funds. Additionally, increasing energy efficiency through infrastructure investments in the energy sector by substituting obsolete infrastructure and equipment would reduce fossil fuels demand, resulting in a reduction in EF.

Secondly, though the FDI enhances the ecological quality in the MINT nations, it is advised that the MINT nations link their FDI initiatives with the goals of ecological conservation regarding future FDI policies. More significantly, the MINT nations should prevent advanced nations from abusing their interest to gain unjustified gains from FDI. For example, MINT nations should not focus on the export and production of products that cause significant pollution while enabling advanced countries to do the same with comparatively lesser polluting goods and services. Additionally, the MINT nations' FDI policies should be revised so as to limit the inflows of dirty FDI. Instead, the MINT countries should work to entice greener FDI, which may also aid in technological innovation *via* a technique known as knowledge spillover. Finally, as FD does not help to reduce EF, the MINT nations should seek to green their financial sectors. Efforts to introduce green finance strategies must be prioritized, and encouraging investment in green projects is crucial. As a result, climate funding is essential for improving the ecological implications connected to FD. It is also advised that the MINT nations deploy their resources to finance programs to combat climate change.

5.3 Study limitation and future path

The stumbling block in this research was the lack of data for recent years; as a result, the research period was restricted to the period between 1990 and 2018. This research might be expanded to consider the social and cultural aspects within the analytical framework as far as future study initiatives are concerned. In addition, the pollution halo and/or haven hypothesis may be used to analyze how the combined effect of FDI and renewable energy impact EF. Lastly, using the nonlinear panel ARDL to examine the asymmetric effects of population density, renewable energy, economic growth, financial development, and foreign direct investment on the MINT nations' ecological footprint may also be considered.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The reviewer MM declared a past co-authorship with the author TSA to the handling editor.

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References

Abbasi, K. R., Shahbaz, M., Zhang, J., Irfan, M., and Alvarado, R. (2022). Analyze the environmental sustainability factors of China: The role of fossil fuel energy and renewable energy. *Renew. Energy* 187, 390–402. doi:10.1016/j.renene.2022.01.066

Acheampong, A. O., Adams, S., and Boateng, E. (2019). Do globalization and renewable energy contribute to carbon emissions mitigation in Sub-Saharan Africa? *Sci. Total Environ.* 677, 436–446. doi:10.1016/j.scitotenv.2019.04.353

Acheampong, A. O. (2018). Economic growth, CO2 emissions and energy consumption: What causes what and where? *Energy Econ.* 74, 677–692. doi:10.1016/j.eneco.2018.07.022

Adebayo, T. S. (2022a). Environmental consequences of fossil fuel in Spain amidst renewable energy consumption: A new insights from the wavelet-based granger causality approach. *Int. J. Sustain. Dev. World Ecol.* 29, 579–592. doi:10.1080/13504509.2022.2054877

Adebayo, T. S. (2022b). Impact of financial globalization on environmental degradation in the E7 countries: Application of the hybrid nonparametric quantile causality approach. *Probl. Ekorozwoju* 17, 148–160. doi:10.35784/pe.2022.2.16

Adebayo, T. S. (2022c). Renewable energy consumption and environmental sustainability in Canada: Does political stability make a difference? *Environ. Sci. Pollut. Res.* 29, 61307–61322. doi:10.1007/s11356-022-20008-4

Ahmad, M., Ahmed, Z., Yang, X., Hussain, N., and Sinha, A. (2022). Financial development and environmental degradation: Do human capital and institutional quality make a difference? *Gondwana Res.* 105, 299–310. doi:10.1016/j.gr.2021.09.012

Ahmad, M., Jiang, P., Murshed, M., Shehzad, K., Akram, R., Cui, L., et al. (2021). Modelling the dynamic linkages between eco-innovation, urbanization, economic growth and ecological footprints for G7 countries: Does financial globalization matter? *Sustain. Cities Soc.* 70, 102881. doi:10.1016/j.scs.2021.102881

Al-mulali, U., Tang, C. F., and Ozturk, I. (2015). Does financial development reduce environmental degradation? Evidence from a panel study of 129 countries. *Environ. Sci. Pollut. Res.* 22, 14891–14900. doi:10.1007/s11356-015-4726-x

Ali, Q., Yaseen, M. R., Anwar, S., Makhdum, M. S. A., and Khan, M. T. I. (2021). The impact of tourism, renewable energy, and economic growth on ecological footprint and natural resources: A panel data analysis. *Resour. Policy* 74, 102365. doi:10.1016/j.resourpol.2021.102365

Ali, S., Can, M., Shah, M. I., Jiang, J., Ahmed, Z., and Murshed, M. (2022). Exploring the linkage between export diversification and ecological footprint: Evidence from advanced time series estimation techniques. *Environ. Sci. Pollut. Res.* 29, 38395–38409. doi:10.1007/s11356-022-18622-3

Anwar, A., Sinha, A., Sharif, A., Siddique, M., Irshad, S., Anwar, W., et al. (2022). The nexus between urbanization, renewable energy consumption, financial development, and CO2 emissions: Evidence from selected asian countries. *Environ. Dev. Sustain.* 24, 6556–6576. doi:10.1007/s10668-021-01716-2

Awosusi, A. A., Xulu, N. G., Ahmadi, M., Rjoub, H., Altuntaş, M., Uhunamure, S. E., et al. (2022). The sustainable environment in Uruguay: The roles of financial development, natural resources, and trade globalization. *Front. Environ. Sci.* 10. doi:10.3389/fenvs.2022.875577

Balcilar, M., Ozdemir, Z. A., Tunçsiper, B., Ozdemir, H., and Shahbaz, M. (2020). On the nexus among carbon dioxide emissions, energy consumption and economic growth in G-7 countries: New insights from the historical decomposition approach. *Environ. Dev. Sustain.* 22, 8097–8134. doi:10.1007/s10668-019-00563-6

Beton Kalmaz, D., and Awosusi, A. A. (2022). Investigation of the driving factors of ecological footprint in Malaysia. *Environ. Sci. Pollut. Res.* 29, 56814–56827. doi:10.1007/s11356-022-19797-5

Cetin, M., Demir, H., and Saygin, S. (2021). Financial development, technological innovation and income inequality: Time series evidence from Turkey. *Soc. Indic. Res.* 156, 47–69. doi:10.1007/s11205-021-02641-7

Charfeddine, L., and Kahia, M. (2019). Impact of renewable energy consumption and financial development on CO2 emissions and economic growth in the MENA region: A panel vector autoregressive (PVAR) analysis. *Renew. Energy* 139, 198–213. doi:10.1016/j.renene.2019.01.010

DanishHassan, S. T., Baloch, M. A., Mahmood, N., and Zhang, J. (2019). Linking economic growth and ecological footprint through human capital and biocapacity. *Sustain. Cities Soc.* 47, 101516. doi:10.1016/j.scs.2019.101516

Destek, M. A., and Sarkodie, S. A. (2019). Investigation of environmental Kuznets curve for ecological footprint: The role of energy and financial development. *Sci. Total Environ.* 650, 2483–2489. doi:10.1016/j.scitotenv.2018.10.017

Djellouli, N., Abdelli, L., Elheddad, M., Ahmed, R., and Mahmood, H. (2022). The effects of non-renewable energy, renewable energy, economic growth, and foreign direct investment on the sustainability of African countries. *Renew. Energy* 183, 676–686. doi:10.1016/j.renene.2021.10.066

Du, L., Jiang, H., Awosusi, A. A., and Razzaq, A. (2022). Asymmetric effects of high-tech industry and renewable energy on consumption-based carbon emissions in MINT countries. *Renew. Energy* 196, 1269–1280. doi:10.1016/j.renene.2022.07.028

Dumitrescu, E.-I., and Hurlin, C. (2012). Testing for Granger non-causality in heterogeneous panels. *Econ. Model.* 29, 1450–1460. doi:10.1016/j.econmod.2012.02.014

Eskeland, G. S., and Harrison, A. E. (2003). Moving to greener pastures? Multinationals and the pollution haven hypothesis. *J. Dev. Econ.* 70, 1–23. doi:10.1016/S0304-3878(02)00084-6

Faisal, F., Pervaiz, R., Ozatac, N., and Tursoy, T. (2021). Exploring the relationship between carbon dioxide emissions, urbanisation and financial deepening for Turkey using the symmetric and asymmetric causality approaches. *Environ. Dev. Sustain.* 23, 17374–17402. doi:10.1007/s10668-021-01385-1

Grossman, G. M., and Krueger, A. B. (1995). Economic growth and the environment. *Q. J. Econ.* 110, 353–377. doi:10.2307/2118443

Gyamfi, B. A., Bekun, F. V., and Agboola, M. O. (2022). Sterling insights into natural resources intensification, ageing population and globalization on environmental status in Mediterranean countries. *Energy & Environ.*, 0958305X2210832. doi:10.1177/0958305X221083240

Hanif, I., Faraz Raza, S. M., Gago-de-Santos, P., and Abbas, Q. (2019). Fossil fuels, foreign direct investment, and economic growth have triggered CO2 emissions in emerging Asian economies: Some empirical evidence. *Energy* 171, 493–501. doi:10.1016/j.energy.2019.01.011

Hashem Pesaran, M., and Yamagata, T. (2008). Testing slope homogeneity in large panels. *J. Econom.* 142, 50–93. doi:10.1016/j.jeconom.2007.05.010

Ibrahim, R. L., Awosusi, A. A., Ajide, K. B., Adewuyi, A. O., and Bolarinwa, F. O. (2022). Investigating the asymmetric effects of renewable energy-carbon neutrality nexus: Can technological innovation, trade openness, and transport services deliver the target for Germany? *Energy & Environ.*, 0958305X2211270. doi:10.1177/0958305X221127020

Jahanger, A., Usman, M., Murshed, M., Mahmood, H., and Balsalobre-Lorente, D. (2022). The linkages between natural resources, human capital, globalization, economic growth, financial development, and ecological footprint: The moderating role of technological innovations. *Resour. Policy* 76, 102569. doi:10.1016/j.resourpol.2022.102569

Kartal, M. T., Depren, S. K., Kirikkaleli, D., Depren, Ö., and Khan, U. (2022). Asymmetric and long-run impact of political stability on consumption-based carbon dioxide emissions in Finland: Evidence from nonlinear and Fourier-based approaches. *J. Environ. Manage.* 321, 116043. doi:10.1016/j.jenvman.2022.116043

Kartal, M. T. (2022). Production-based disaggregated analysis of energy consumption and CO2 emission nexus: Evidence from the USA by novel dynamic ARDL simulation approach. *Environ. Sci. Pollut. Res. Int.* 2 (7), 193–211. doi:10.1007/s11356-022-22714-5

Kashem, M. A., and Rahman, M. M. (2019). CO2 emissions and development indicators: A causality analysis for Bangladesh. *Environ. Process.* 6, 433–455. doi:10.1007/s40710-019-00365-y

Kirikkaleli, D., and Adebayo, T. S. (2021). Do renewable energy consumption and financial development matter for environmental sustainability? New global evidence. *Sustain. Dev.* 29, 583–594. doi:10.1002/sd.2159

Machado, J. A. F., and Santos Silva, J. M. C. (2019). Quantiles via moments. *J. Econom.* 213, 145–173. doi:10.1016/j.jeconom.2019.04.009

Meng, X., and Han, J. (2018). Roads, economy, population density, and CO2: A city-scaled causality analysis. *Resour. Conserv. Recycl.* 128, 508–515. doi:10.1016/j.resconrec.2016.09.032

Murshed, M., Saboori, B., Madaleno, M., Wang, H., and Doğan, B. (2022). Exploring the nexuses between nuclear energy, renewable energy, and carbon dioxide emissions: The role of economic complexity in the G7 countries. *Renew. Energy* 190, 664–674. doi:10.1016/j.renene.2022.03.121

Nathaniel, S. P., Yalçiner, K., and Bekun, F. V. (2021). Assessing the environmental sustainability corridor: Linking natural resources, renewable energy, human capital, and ecological footprint in BRICS. *Resour. Policy* 70, 101924. doi:10.1016/j.resourpol.2020.101924

Odugbesan, J. A., and Rjoub, H. (2020). Relationship among economic growth, energy consumption, CO2 emission, and urbanization: Evidence from MINT countries. *SAGE Open* 10, 215824402091464. doi:10.1177/2158244020914648

Ojekemi, O. S., Rjoub, H., Awosusi, A. A., and Agyekum, E. B. (2022). Toward a sustainable environment and economic growth in BRICS economies: Do innovation and globalization matter? *Environ. Sci. Pollut. Res.* 29, 57740–57757. doi:10.1007/s11356-022-19742-6

O'Neill, J. (2013). Who you calling a BRIC. *Bloom. View* 12, 63–79.

Ozturk, I., and Acaravci, A. (2016). Energy consumption, CO_2emissions, economic growth, and foreign trade relationship in Cyprus and Malta. *Energy Sources Part B Econ. Plan. Policy* 11, 321–327. doi:10.1080/15567249.2011.617353

Pata, U. K., and Samour, A. (2022). Do renewable and nuclear energy enhance environmental quality in France? A new EKC approach with the load capacity factor. *Prog. Nucl. Energy* 149, 104249. doi:10.1016/j.pnucene.2022.104249

Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross-section dependence. *J. Appl. Econ. Chichester. Engl.* 22, 265–312. doi:10.1002/jae.951

Pesaran, M. H. (2006). Estimation and inference in large heterogeneous panels with a multifactor error structure. *Econometrica* 74, 967–1012. doi:10.1111/j.1468-0262.2006.00692.x

Pesaran, M. H. (2015). Testing weak cross-sectional dependence in large panels. *Econom. Rev.* 34, 1089–1117. doi:10.1080/07474938.2014.956623

Rehman, A., Ma, H., Ozturk, I., Murshed, M., and Dagar, V. (2021). The dynamic impacts of CO2 emissions from different sources on Pakistan's economic progress: A roadmap to sustainable development. *Environ. Dev. Sustain.* 23, 17857–17880. doi:10.1007/s10668-021-01418-9

Samour, A., Baskaya, M. M., and Tursoy, T. (2022a). The impact of financial development and FDI on renewable energy in the uae: A path towards sustainable development. *Sustainability* 14, 1208. doi:10.3390/su14031208

Samour, A., Moyo, D., and Tursoy, T. (2022b). Renewable energy, banking sector development, and carbon dioxide emissions nexus: A path toward sustainable development in South Africa. *Renew. Energy* 193, 1032–1040. doi:10.1016/j.renene.2022.05.013

Shahbaz, M., Balsalobre-Lorente, D., and Sinha, A. (2019). Foreign direct Investment–CO2 emissions nexus in Middle East and North African countries: Importance of biomass energy consumption. *J. Clean. Prod.* 217, 603–614. doi:10.1016/j.jclepro.2019.01.282

Shahbaz, M., Nasir, M. A., and Roubaud, D. (2018). Environmental degradation in France: The effects of FDI, financial development, and energy innovations. *Energy Econ.* 74, 843–857. doi:10.1016/j.eneco.2018.07.020

Shahbaz, M., Shahzad, S. J. H., Ahmad, N., and Alam, S. (2016). Financial development and environmental quality: The way forward. *Energy Policy* 98, 353–364. doi:10.1016/j.enpol.2016.09.002

Sunday Adebayo, T., Saint Akadiri, S., Haouas, I., and Rjoub, H. (2022). A time-varying analysis between financial development and carbon emissions: Evidence from the MINT countries. *Energy & Environ.*, 0958305X2210820. doi:10.1177/0958305X221082092

Teal, F., and Eberhardt, M. (2020). *Productivity analysis in global manufacturing production*. England: University of Oxford.

Usman, O., Akadiri, S. S., and Adeshola, I. (2020). Role of renewable energy and globalization on ecological footprint in the USA: Implications for environmental sustainability. *Environ. Sci. Pollut. Res.* 27, 30681–30693. doi:10.1007/s11356-020-09170-9

Westerlund, J. (2008). Panel cointegration tests of the Fisher effect. *J. Appl. Econ. Chichester. Engl.* 23, 193–233. doi:10.1002/jae.967

Wu, L., Yue, X.-G., and Umut, A. (2022). The role of renewable energy consumption and financial development in environmental sustainability: Implications for the nordic countries. *Int. J. Sustain. Dev. World Ecol.* 0, 1–16. doi:10.1080/13504509.2022.2115577

Xie, Q., Wang, X., and Cong, X. (2020). How does foreign direct investment affect CO2 emissions in emerging countries?New findings from a nonlinear panel analysis. *J. Clean. Prod.* 249, 119422. doi:10.1016/j.jclepro.2019.119422

Xu, L., Wang, X., Wang, L., and Zhang, D. (2022). Does technological advancement impede ecological footprint level? The role of natural resources prices volatility, foreign direct investment and renewable energy in China. *Resour. Policy* 76, 102559. doi:10.1016/j.resourpol.2022.102559

Zarco-Periñán, P. J., Zarco-Soto, I. M., and Zarco-Soto, F. J. (2021). Influence of population density on CO2 emissions eliminating the influence of climate. *Atmosphere* 12, 1193. doi:10.3390/atmos12091193

Zhang, L., Li, Z., Kirikkaleli, D., Adeshola, I., and Akinsola, G. D. (2021). Modeling CO2 emissions in Malaysia: An application of maki cointegration and wavelet coherence tests. *Environ. Sci. Pollut. Res.* 28, 26030–26044. doi:10.1007/s11356-021-12430-x

Zhang, Q., Ibrahim, R. L., and Al-Faryan, M. A. S. (2022). Do the asymmetric effects of technological innovation amidst renewable and nonrenewable energy make or mar carbon neutrality targets? *Int. J. Sustain. Dev. World Ecol.* 0, 1–13. doi:10.1080/13504509.2022.2120559