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EXPLORING THE EFFECT OF GREEN FINANCE, FINANCIAL INNOVATION AND ENVIRONMENTAL SUSTAINABILITY IN MINT COUNTRIES

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Abstract

This study investigates the effects of green finance and financial innovation on environmental sustainability as measured using ecological footprint in MINT countries such as Mexico, Indonesia, Nigeria, and Turkeys, from 2007 to 2021. This study makes a significant contribution to literature as it examines the effects of green financing and financial innovation in emerging economies like the MINT countries which are classified as frontier markets. In examining the environment - finance linkages, the authors employed Environmental Kuznets Curve (EKC) theory, Fixed Effect Model (FEM), co-integration test and Fully Modified OLS (FMOLS) to account for individual unique effects of the cross section and time periods within the data; and to estimate the equilibrium relationship amongst the variables in the long run. The study found that the long run estimate of green and innovative financing is significantly positive in combatting ecological challenges in MINT countries. The study strongly recommends the expansion of, and critical investments in renewable energy, increased investment in research and development in green technologies to halt environmental deterioration.

Keywords: Green Finance, Financial Innovation, Ecological Footprint, MINT Countries, Environmental Sustainability.

1. INTRODUCTION

The United Nations Sustainable Development Goal (SDG) 13 addresses climate action and allied activities that must be carried out by nations and corporations to protect the climate and the environment in general, for current and future generations. Tied to this goal are SDGs 11 (building sustainable cities and communities) and 12 (responsible consumption and production) which seeks to promote ecological and societal

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preservation by encouraging eco-friendly consumption and production processes. In this regard, current generation, scholarship, and world leaders appear to have realized the importance of a sustainable environment through the instrumentality of green finance. Green finance, in the view of Peng and Zheng (2021), refers to the various economic activities that are geared towards revitalizing the environment on one hand and optimizing resource usage on the other. This, according to them, relates to the use of clean and safe energy, sustainable energy usage and consumption, sustainable transportation and promotion of green buildings.

The attainment of an eco-friendly and sustainable environment through green finance is no mean feat. This is why Zhang et al. (2021), notes that for governments and corporations to pursue the financial innovation of green finance, it needs to take into consideration the economic costs and benefits thereof. In fact, proponents of green economy aver that green finance provides a functional way to satisfy the financial demands of governments, businesses and corporations engaged in activities and initiatives that protects the environment in a sustainable way (Falcone and Sica 2019), and alienate the others that do not. For Li et al. (2022), a green finance system development helps in the technological advancement of the energy sector. As a result, green finance and its role in the funding and development of technological capabilities that promote environmental sustainability has become a vital resource in improving human lives, welfare, and environmental performance. Therefore, the challenge of ensuring a sustainable and resilient environmental performance has now become an important issue that emerging economies around the world must grapple with.

As per Wang et al. (2022) and Zhou et al. (2020), there is a nexus between green finance and environmental performance, suggesting that financial instruments can be potent in addressing environmental issues. Consequently, leading and top global economies are expected to pay much attention to the subject matter of green finance in order achieve both economic and environmental sustainability. Notably, not all scholars agree with the deepening and growing influence of green finance in emerging and even top economies. Others even view it in tandem with other innovations as blue finance, digital finance, financial innovation and financial development (Ozili 2021a).

For Huang et al. (2019), green finance is a relatively new financial innovation that makes provision for a novel kind of financial assistance for governments, people and businesses who are keen on participating in green initiatives or low carbon consumption and production processes. This kind of funding attracts some advantages for all concerned in the environment. Some of the advantages of green finance as outlined by Sachs et al. (2019) includes environmental preservation, low-risk financing, financing of sustainable business operations and investments, creation of green investments and its associated financing instruments. Yang (2020) note that the benefit of green finance to governments and businesses will not have been possible without financial innovation and development. In spite of the advantages that green finance provides; it is important to note that it is just

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one aspect of financial innovation for sustainable finance in achieving sustainable development (Ozili 2021b)

Financial innovation has been conceived as a medium that helps fund environmental initiatives as it supports green innovation through the promotion of stringent environmental laws (Huo, et Al. 2022). In addition, green finance development and financial innovation has attracted much attention in recent times, especially in the context of production function, theoretical framework and role of technology in the economy. The major focus of these areas, been environmental quality, has to be improved as it is now a major concern of sustainable development in the world today; arising from the need to save our environment for future generations (Nasim et al. 2022; Nisar et al. 2022).

Instructively, environmental quality determines the quality of life of a given population. With advancement in industrialization comes rising pollution that affects living creatures in different forms. As the environment deteriorates incrementally, it therefore becomes imperative to clean this toxic environment through the machinations of financial innovation and green finance with great levels of intentionality. Rafique et al. (2022), avers those negative environmental consequences caused by pollutions induced by industrialization have negative effects in the protection of human health which underscores the major purpose of human existence. According the author, the environment is not a private concern but a public one, as it is no secret that a defective environment poses a threat to humanity and affronts its goals for a better and quality life.

In the light of the foregoing, the challenge of investors in contemporary times have been on how to maximize profit on one hand, and to create a sustainable economy that will benefit all on the other. But by combining green finance and financial innovation, a bridge between the two extremes can be built, especially in ways that promotes sustainable growth and development in a natural way. In line with the above, it is evident that there is a dearth of literature on the impact of green finance and financial innovation on the quality of the environment in MINT countries.

Notably, extant literature provided mixed evidence on environmental quality, as the literature focuses mainly on using carbon dioxide (CO_2) emission as measure for environmental quality and sustainability. This study however, used ecological footprint (EF) to serve as proxy for environmental sustainability. Fundamentally, EF is considered as a wholesome and prolific indicator of environmental sustainability, as it captures all anthropogenic water, air and soil (Kihombo et al. 2021; Erdogan et al. 2020). On the other hand, measuring environmental sustainability using carbon footprint and CO_2 emissions as indicators only capture the potential impact of energy consumption (Ullah, et al. 2020). In this regard, this study follows this new thinking by adopting EF as a veritable proxy for environmental sustainability, as well environmental deterioration.

In order to bridge the existing gap in literature, this study examines how green finance and financial innovation impacts environmental sustainability over a 15-year period with particular focus on Mexico, Indonesia, Nigeria and Turkey (MINT) countries. The study

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contributes to literature on the subject matter by interrogating the influence of financial innovation and green finance environmental quality and sustainability. Findings arising from this study will be of immense benefit for concerned stakeholders. Furthermore, the originality of this research is contained in the geographical landscape of MINT countries especially on how green finance and financial innovation impacts environmental sustainability within the countries of study. Although, there is no research to the knowledge of the authors in these countries as a block to know if there is a direct impact of green finance and financial innovation on environmental sustainability and quality. While analysis in other literature focuses on using the green finance index, this aspect of our study focuses on the importance of financial innovation and green financing of renewable energy initiatives in MINT countries, thereby adding to the existing body of knowledge on green finance and financial innovation.

2. LITERATURE REVIEW

This section is divided into two thus: (i) Green finance and environmental sustainability and (ii) Financial Innovation and environmental sustainability.

2.1 Green Finance and Environment Sustainability

To begin with, it is important to state from the outset that green finance is the link between the economy and the environment. The growth of green finance in recent times have been vital in the attainment of sustainable development goals on one hand and addressing mounting environmental challenges on the other (Goel et al. 2022). One key aspect of green finance is that it redirects vital resources from companies and businesses that pollutes the environment towards investments and businesses that benefits the environment. Green finance makes funding available to achieve sustainable development.

In this regard, financial institutions are enjoined to ecological preservation and pollution into consideration when making finance decisions in the form of granting of loans and other financial packages to investors (Akomea-Frimpong et al. 2022). This is simply the use of use of financial incentives and leverage in protecting the environment and ensuring its sustainability and quality.

This goes a long way to prevent the growth and development of environmentally irresponsible businesses and investments. In addition, green credits and other market innovations are very much successful in guaranteeing environmental protection than conventional financial institutions. Notably, governments now use green credits a powerful financial weapon to direct financial institutions resource allocation to investments and businesses that environmentally friendly and conscious (Bhatnagar et al. 2022).

Green economists have also suggested that green finance provides a sustainable means of satisfying the financial demands of businesses, private citizens and government entities involved in operations and initiatives that promotes and protect the environment sustainably (Falcone & Sica 2019). Green finance equally has the prospect of enhancing

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accessibility and transparency of the market in relation to eco-friendly projects and investments. Earlier studies on green finance have variously highlighted the importance of green finance in advancing environmental sustainability within countries.

A study by Pang et al (2022) investigated the efficacy of green finance using the Wavelet-based quantile to qunatile approach. According to the authors, green finance effectiveness varies from to country to country as a result of weak government regulation of green finance sector and poor financial development initiatives. Conceptually, Akomea-Frimpong et al (2022) examines how green finance can promote eco-friendly investments and projects.

The authors stressed that transparency, regulations of financial markets and widespread social awareness are the three major pillars that could spur success for green finance initiatives. By using a global data panel approach, Wang et al. (2022), investigated the nexus between green and economic sustainability. The findings of the authors show that green finance increased sustainability outcomes as it accelerated green capital formulation and accumulation, as well as increasing the participation of the private sector in green investments and projects.

As it employed the Method of Moment Quantile Regression (MMQR), Umar and Safi (2023) assessed the impact of the green finance efficiency amongst OECD member countries. In their study, the authors found that green finance significantly contributed to the reduction of carbon emissions.

It however, equally document that green finance require inclusivity and transparency to expand its importance to a wider array of social issues and classes. Wang and Fan (2023) focuses on China with the aim of identifying the features of green finance impacts investors' decision making.

Their study found that green finance has the potential to guarantee to a reasonable extent, returns on investment, as it also lessens investment risks by making sustainable investments more attractive to investors. For Shang et al. (2023), the issuance of green bonds has a significant positive effect on long-term green efficiency in Chinese tourism sector.

2.1.2. Financial Innovation and Environment Sustainability

As a veritable instrument used in funding environmental initiative for sustainable development purposes, financial innovation is very supportive to the economically disadvantaged who are often in need of scarce resources to invest in clean technologies that will ensure environmental sustainability through the generation and emission of lower levels CO_2.

Technological investments of firms in businesses that are eco-friendly becomes realizable through increased access to financial services. According to Le et al. (2021), to better grasp the benefit and positive effects of financial innovation on the environment, it is imperative that an inclusive financial system is created that drives increased financial

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accessibility, and affordability, with a buy in for the adoption of high-quality pollution regulations. The increased accessibility of financial services will encourage the acceptance and employment of green technologies by making the process of accessing funds for crucial and beneficial environmental projects seamless. On the flip side, increased accessibility of financial services for uncontrolled investments could lead to increased industrial and manufacturing output, which will likely raise carbon emissions and other environmental problem (Qin et al. 2021).

Simulated intelligence, digital assistants, mobile applications and machine learning technologies are often employed by practitioners of financial innovation to provide help and guide to individuals, entrepreneurs and company owners in more efficient ways of managing their financial lives, procedures and operations. In this regard, it is projected that by 2030, economic output from environmentally friendly investments and development will reach \$12trillion, creating 380million jobs (Business & Sustainable Development Commission 2017). More benefit of financial innovation in guaranteeing environmental sustainability is reduces waste production as assist investors in directing their resources to an eco-friendlier initiative through the use of cutting-edge technological solutions like big data analytics, green tech applications and even cryptocurrency for payment solutions.

Improving on the above reviewed literature, this study differs from them as it utilises ecological footprint which is a better accounting tool that measures the amount of the earth’s bio-capacity demanded by a given activity. In this case, the present study investigates the combined effects of green finance and financial innovation on ecological pressures in Mexico, Indonesia, Nigeria and Turkey (MINT countries) from 2007 – 2021, as the study fills this gap in literature.

2.2. Theoretical Background

This study was based on the Environmental Kuznets Curve (EKC) theory espoused by Kuznets (1955). The EKC offers empirical and factual evidence for an inverted-U relationship between environmental sustainability and income levels. The basic assumption of EKC is that as economies gets richer, environmental impacts rises initially and then falls as a result of investments in technologies and enactment and strict implementation of environmental legislations. According to Stern (2014), in reality, some developed economies have experienced reduction in environmental degradation, while others have not. The EKC is commonly split into three stages viz: the early stage of economic growth and development is chiefly characterized by a voracious use of environmental resources leading to increase in environmental degradation. The next stage is the turning point which is achieved as income levels peaks and a change in the pollution dynamics begins to occur.

The last stage is characterized by the mitigation of environmental degradation (Leal & Marques 2022). This, according to the theory is achieved through the use and distribution of clean technology and innovation such as green technology, green finance and financial

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innovation and development, which are the focus of this study. The above explains the rationale for the adoption of the EKC hypothesis in green finance, financial innovation and environmental sustainability in this study.

Thus, as ecological footprint increases, economic growth follows as a result of industrialization, with its attendant polluting effects. As this becomes the case, income levels get to increase leading to increases in green finance and financial innovation. Following this, the trend of environmental degradation arising from emissions reverses due to advancement and investment in green technology and improved environmental laws which contribute to environmental benefits.

3. METHODOLOGY

To achieve the objective of the study, data were gleaned from four geopolitical regions and analyzed quantitatively. The sample obtained for the study were from four heterogeneous cross-sections time series of 15 years from 2007 - 2021. The panel data developed for the study also considered the individual heterogeneity, and analysis were done using the fixed effect model (FEM).

3.1. Research design and method

The study is both empirical and quantitative, as it involves a panel of four regions (Mexico, Indonesia, Nigeria, and Turkeys) from 2007 - 2021. In view of the fact that all the regions are demographically and geographically, the study considers all them heterogeneous. The heterogeneity of the countries was captured using the FEM. The data were collected from various sources, such as the International Energy Agency, Global footprint network (GFN), and world development data bank.

Environmental sustainability is measured through ecological footprint (EF) which comprises of six variables such as: cropland, forestry, fishing grounds, carbon emission, built-up land, and grazing lands; that are aggregated into one variable. Green finance is measured by Investment in Renewable Energy (IRE). Research and Development Expenditure (RDE) as a % of GDP was used in measurement of financial innovation. The control variables used in the study are GDP per capita constant and Energy Consumption (EC) measured by energy use in kg of oil equivalent per capita. A tabular representation of the variables is shown in table 1.

Table 1: Variable Definition

S/N	Indicators Name	Measurement	Source	Variable Code
1	Green finance development	Investment in Renewable Energy	WDI	IRE
2	Financial Innovation	Research and development (R&D) expenditure as a % of GDP	WDI	RDE
3	Environmental Sustainability	Ecological footprint	GFN	EF
4	Control Variables	Gross domestic product per capita constant and energy consumption	WDI	GDP EC

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3.2. Graphical Presentation of Dataset

According to Rana and Sharma (2018), a graphical presentation of a series data is often important before venturing into any analysis. This is because it helps in deciding the direction of a given analysis in the study for precise result. In the light of this, the study proceeds to making a graphical presentation of the trends of each of the variables.

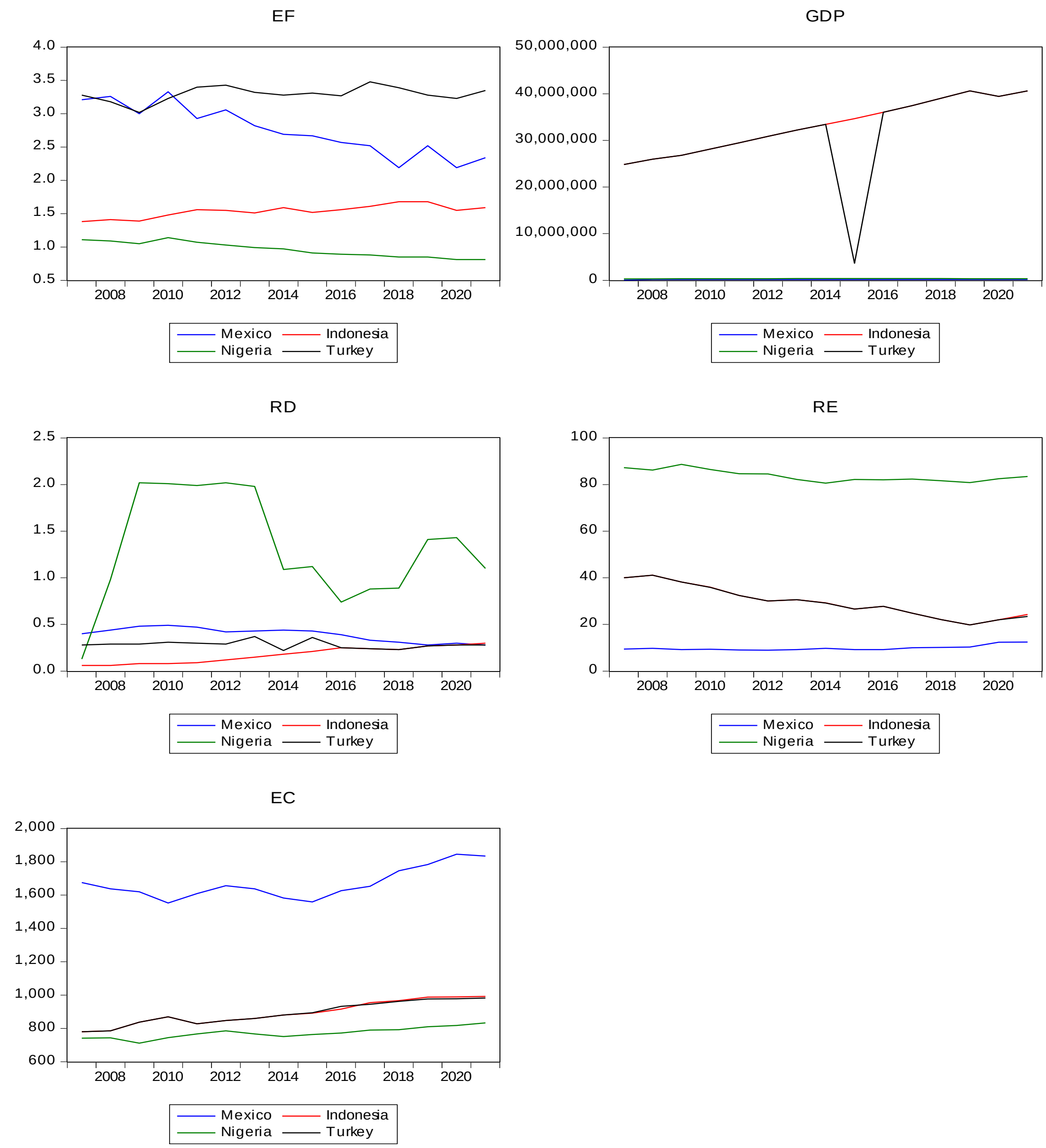

Figure 1: Graphical Presentation of each Set of Data

(Individual Cross Section of Data)

Source: Computed by the authors

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As can be seen in figure 1, environmental sustainability as proxied by ecological footprint (EF) instead of CO_2 allows for a broader assessment for sustainability as it considers the overall environment rather than focusing solely on per carbon emission. Turkey is relatively higher than other MINT countries under study as it ranges from 3.2 to 3.5 while that of Nigeria has lower ecological footprint which ranges from 1.2 to 0.7. However, the Gross domestic Product per capita (GDP) for Turkey decline tremendously from 2014 to 2016 while Indonesia showed a relatively stable GDP growth over the years. Financial innovation and green finance as proxied by research and development expenditure (RDE) and investment in renewable energy (IRE) of Mexico, Indonesia and Turkey seems to be on the low during the period under study, as the trend for Nigeria showed a significant growth from 2008 to 2014 before declining in 2016. Energy consumption (EC) for Mexico showed a high trend with Nigeria showing the lowest of all the countries under review.

3.3. Common Constant or Pooled Ordinary Least Square (OLS)

The first step adopted by the authors was to check for the suitability of Common Constant Methods or pooled OLS in conducting the analyses of the study. The basic assumption of the CCM is that there are no differences in the cross-section units or time period in the panel data. In this regard, it is equally assumed that the cross-sectional units in the panel data are homogeneous and invariant with time, as shown in table 2.

Table 2: Pooled OLS/Common Constant Method Test

Variable	Coefficient	Std. Error	t-Statistic	Prob.
EC	-0.001988	0.000864	-2.301588	0.0252
GDP	-2.48E-08	1.38E-08	-1.794713	0.0782
IRE	-0.052141	0.011940	-4.367037	0.0001
RDE	0.324388	0.274447	1.181967	0.2423
C	6.457086	1.519769	4.248728	0.0001
R-squared	0.567638	Mean dependent var		2.137667
Adjusted R-squared	0.536193	S.D. dependent var		0.959782
F-statistic	18.05203	Durbin-Watson stat		0.135589
Prob(F-statistic)	0.000000			

Source: computed by authors

While the R-squared value at 56.7% shows a predictive and explanatory power, it is however problematic since the value is greater than the Durbin-Watson value, suggesting a biased regression that might have been caused by autocorrelation in the model due to specification error. Also, the model assumes that the intercept value and slope coefficients of the explanatory variables are identical, common or the same and does not have specific effects nor vary amongst the cross-sectional units and time periods.

In spite of this simplistic analogy, the pooled OLS may have highly distorted the true picture of the relationship that exist between dependent variable (EF) and the independent variables (GDP, IRE, RDE and EC) amongst the cross-sectional units (MINT) and time periods (15years)

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A Brusche Pagan test conducted also show that OLS regression was unsuitable for the model. The Brusche Pagan test assumes the null hypothesis stating that there are no effects in pooled OLS regression within the cross section and time series, making it suitable and stable for the model; while the alternate hypothesis states that there are effects across the cross section and time series in panel data.

As the *P* value of Breusch Pagan Test for cross section and time elements is less than 0.05 as shown in table 3; we reject the null hypothesis. This means that pooled OLS is not stable. Therefore, we adopted the fixed effects Methods (FEM) in our regression analysis.

Table 3: Brusche Pagan Test

Cross section	Time	Both
322.8750	5.726458	328.6015
(0.0000)	(0.0167)	(0.0000)

Source: computed by authors

3.4. Fixed Effects Model (FEM)

The next step adopted by the authors was to check for the effects of heterogeneous properties of the individual cross section and time series and account for them so as not to fall into the problem of endogeneity wherein the error term gets correlated with one of the regressors in the models. Thus, in line with Ozturk and Ullah (2022) and Khan et al. (2022), we state the following econometric model:

$$EF = \beta_0 + \beta_1 GDP + \beta_2 RDE + \beta_3 IRE + \beta_4 EC + \varepsilon \quad (1)$$

Equation 1 shows the normal panelled OLS regression which does not account for fixed account for the cross section and time series characteristics. In this model EF (Ecological Footprint) is the dependent variable; while GDP (Gross Domestic Product), RDE (Research and Development Expenditure), IRE (Investment in Renewable Energy), and EC (Energy Consumption) are all the independent variables. B_0 represents the intercept or constant, while $B_{1,\ 2,\ 3,\ 4}$ all represent the parameter estimators for the independent variables. ε is the error term.

$$EF_{it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 RDE_{it} + \beta_3 IRE_{it} + \beta_4 EC_{it} + \varepsilon_{it} \quad (2)$$

In equation 2, the cross-sectional properties and time series dimensions were introduced and represented by *i* and *t* respectively. Yet the unobserved heterogeneity arising from the panel data was still missing. This leads us to estimating equation 3 as we added the two error terms $\mu_t$andω_i.

$$EF_{it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 RDE_{it} + \beta_3 IRE_{it} + \beta_4 EC_{it} + \mu_t + \omega_i + \varepsilon_{it} \quad (3)$$

The estimation in equation 3 took into consideration the unobserved heterogeneity from time and cross section effects of the panel data, which were the error terms arising from time effects and error terms from cross section effects. Thus, the $\mu_t$in equation 3 stands for the unobserved time dependent error term (i.e., factors affecting Ecological footprints

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that varies with time rather than with the cross-sectional units, e.g., level of industrialization, population growth, biodiversity, environmental awareness, etc.). In the same vein, $\omega_i$is the cross section dependent error term (i. e. factors that may vary with the MINT countries, but are independent of time, e.g., consumption culture, government spending, degree of environmental policy implementation, educational literacy of population, etc.).

Essentially, μ_t is fixed over the cross-sectional units, but varies with time; while ω_i is also fixed over time periods, but varies with the cross-sectional units.

$$EF_{it} = \alpha_1 + \alpha_2 DIND_i + \alpha_3 DNGN_i + \alpha_4 DTUR_i + \lambda_0 + \lambda_1 D_{08} + \lambda_2 D_{09} + \text{----} \lambda_{14} D_{21} + \beta_1 GDP_{it} + \beta_2 RDE_{it} + \beta_3 IRE_{it} + \beta_4 EC_{it} + \mu_{it} \quad (4)$$

Furthermore, in order to account for the time and cross section effects in the model, we introduced dummy variables for the cross-sectional units and time periods. In this regard, we introduced time dummies for 14 years against the 15-year time periods; and 3 cross section dummies as against the 4 cross sectional units in the model.

The reason for this is to avoid falling into the dummy trap and producing unreliable result, as α_1 and λ_0 are already representing the omitted or dropped cross sectional unit (Mexico) and time period (2007) in equation 4. As noted earlier, α_1 represents the omitted cross section unit, as well as the intercept and slopes in the model equation; while λ_0 also represents the omitted time period, as well as the intercept and slopes in the model equation. D represents the dummy variables for time and cross-sectional units; while IND (Indonesia), NGN (Nigeria), and TUR (Turkey).

Therefore, in line with equation 4, the following test was conducted and result shown in table 4. The implication of this result is that contrary to the pooled OLS/Common Constant result in table 2, which assumes the homogeneity of variables within the cross-sectional units and time periods, the FEM test results shows a heterogeneous characteristics and individual specific effects of time and cross-sectional units amongst the variables in the estimated model.

There is no common constant of zero amongst the dummy variables as assumed by pooled OLS in the FEM test. This shows that other unobserved variables also impact the dependent variables significantly in the model as they all have a p-value that is less than 0.05.

In addition, except for years 2008 and 2010 whose p-values are greater than 0.05, all other years in the FEM analysis are statistically significant showing variations over time amongst the variables in the MINT country grouping.

Although, despite these variations however, there is still a long run co-integration of the variables and a long run equilibrium amongst them as shown in table 9 by the Kao (1999) test and Pedroni (2004) tests respectively.

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Table 4: Fixed Effects Model Test

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4.806471	0.617851	7.779337	0.0000
GDP	-9.94E-10	3.52E-09	-0.282641	0.7790
EC	-0.000703	0.000372	-1.890672	0.0663
RD	0.053149	0.050427	1.053985	0.2985
RE	-0.051904	0.004820	-10.76846	0.0000
D2	-0.690570	0.326388	-2.115795	0.0410
D3	1.362312	0.445935	3.054957	0.0041
D4	1.056013	0.323408	3.265263	0.0023
@YEAR=2008	-0.006471	0.068539	-0.094409	0.9253
@YEAR=2009	-0.183351	0.071956	-2.548090	0.0150
@YEAR=2010	-0.082493	0.072331	-1.140498	0.2612
@YEAR=2011	-0.256998	0.073591	-3.492265	0.0012
@YEAR=2012	-0.271744	0.075251	-3.611143	0.0009
@YEAR=2013	-0.395498	0.075596	-5.231715	0.0000
@YEAR=2014	-0.463237	0.073746	-6.281493	0.0000
@YEAR=2015	-0.557102	0.081713	-6.817780	0.0000
@YEAR=2016	-0.518372	0.076158	-6.806533	0.0000
@YEAR=2017	-0.512981	0.080258	-6.391639	0.0000
@YEAR=2018	-0.664922	0.086741	-7.665585	0.0000
@YEAR=2019	-0.669456	0.092918	-7.204788	0.0000
@YEAR=2020	-0.688660	0.093865	-7.336732	0.0000
@YEAR=2021	-0.542005	0.093293	-5.809735	0.0000
R-squared	0.993638	Mean dependent var		2.137667
Adjusted R-squared	0.990122	S.D. dependent var		0.959782
F-statistic	282.6168	Durbin-Watson stat		1.904833
Prob(F-statistic)	0.000000			

Source: computed by authors

3.5. Cross-Section Dependence Test

In addition, the panel shows the interdependence amongst the cross-sectional units. The researchers examined these features of the panel data to determine whether there is a cross section dependence and variation in slopes.

Notably, individual countries in the MINT grouping may show some form of similarity in some of the variables and diverge in others.

Thus, not examining these individual characteristics in the MINT countries under study in the model might lead to a biased analysis and spurious results. For the cross-section dependence test, the Brusche Pagan LM was adopted.

The reason for the adoption of the Brusche Pagan Test is because the study Time Period (T) > Number of Cross Sections in the panel data. Furthermore, to effectively remove the

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cross-section dependence from the panel data, the study used the Generalised Least Square Methods (GLS) and Seemingly Unrelated Regression Model (SUR).

3.6. Unit Roots Test

Next, we test for stationarity amongst the variables under study within the panel in relation to the cross-sectional units and time series dimensions. This test employed for the purpose was the Fisher-Augment Dickey Fuller (ADF) and Fisher-Philip Peron (PP) advanced by Madala and Wu (1999), LLC test by Levine, Lin and Chu (2002) and IPS test by Im, Pesaran and Shin (2003) test of unit root.

Apart from IRE that was integrated at level 1(0), results of the unit root tests show that all variables in the model were integrated at order 1(1). Notably, the unit root test conducted assume a null hypothesis of unit roots (i.e., variable was non-stationary); and an alternate hypothesis of no unit roots (i.e., variables were stationary).

Considering the fact that EF, EC, GDP, RDE and IRE variables in the model were stationary at 1(1) and I(0), which were at a significant level of 5%, the null hypothesis were therefore rejected (see table 8).

3.7. Co-integration Test.

Giving the fact that the panel data in the time series were integrated at order I (0) and 1(1) after first differencing. There is however, a problem with differenced time series to make it stationary. This is so because when we difference a time series data, we run into the problem of incurring loss of vital long run information by eliminating or destroying the long run characteristics of the time series whenever we difference them. Hence, the need for co-integration test.

Having ascertained whether or not there is unit roots in the panel data, it therefore becomes imperative to check if the variables were co-integrated on the long run. In this regard, the Pedroni (2004) co-integration test and the Kao residual co-integration test was used as developed by Kao (1999).

3.8 Fully Modified Ordinary Least Square Test (FMOLS)

Having determined that the variables are co-integrated using the both the Pedroni and Kao tests respectively, we proceed to estimate the long run relationship in the model between EF, GDP, RDE, EC and IRE in the model.

Given the fact that the Ordinary Least Square (OLS) has the possibility of having an inconsistent and biased estimator when applied to co-integrating variables in a model, we however, estimate the long run relationship in the model using FMOLS as prescribed by Pedroni (2000).

The reason for the adoption of FMOLS is that it does not only generate consistent estimators, it also, controls for possible serial correlation and endogeneity associated with the regressors.

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4. RESULTS AND DISCUSSION OF FINDINGS

4.1. Descriptive statistics of the variables

Table 5 shows the descriptive statistics of the study variables. From the descriptive analysis, it is observed that the mean values of Gross Domestic Product (GDP) have the highest mean value of 16267278, while Research and Development Expenditure (RDE) has the lowest mean value of 0.54, compared to other variables in the model. In addition, a model for statistical analysis is said to be robust and fit if the data contained therein, are normally distribution.

Table 5: Descriptive Statistics Result

Parameters	EF	GDP	EC	RDE	IRE
Mean	2.137667	16267278	1055.704	0.542333	38.21783
Median	1.935000	2024237.	880.1200	0.300000	29.24500
Maximum	3.480000	40620816	1845.770	2.020000	88.68000
Minimum	0.810000	18698.96	711.3500	0.060000	8.970000
Std. Dev.	0.959782	17004117	366.3439	0.542900	28.12519
Skewness	0.051431	0.207890	1.084177	1.748714	0.792994
Kurtosis	1.375741	1.213953	2.444562	4.936676	2.087937
Jarque-Bera	6.621995	8.407093	12.52567	39.95680	8.368043
Probability	0.036480	0.014942	0.001906	0.000000	0.015237
Sum	128.2600	9.76E+08	63342.25	32.54000	2293.070
Sum Sq. Dev.	54.34967	1.71E+16	7918262.	17.38967	46670.55
Observations	60	60	60	60	60

Source: Computed by the authors.

Essentially, skewness and kurtosis values determine the normality of the variables in the distribution. While skewness of data in the variables measures the degree of lop-sidedness or asymmetry in the series; kurtosis on the other hand, measures either the flatness or peakness of the series distribution.

Skewness of a distribution is considered normal and symmetric around its mean if it equals zero (0). It is considered positively skewed and long right tailed if the values are more than zero (0); but negatively skewed if it has a value lower than zero (0). In the same vein, a Kurtosis value of 3 is considered mesokurtic and a normal distribution.

If it is less than 3 however, it is considered platykurtic (flat-curved) or negative kurtosis; but leptokurtic or positive kurtosis if it has a value that is more than 3. In view of this, table 5 shows that EF, GDP and IRE exhibits a normal skewness and distribution as their values are within 0; but have platykurtic kurtosis as their values are lower than 3.

Also, while EC and RDE have long right tail or positive skewness as their values are greater 0, only RDE has a leptokurtic kurtosis because of its higher value of 4.9 which was greater than 3; while EC remained platykurtic like the other variables analysed earlier.

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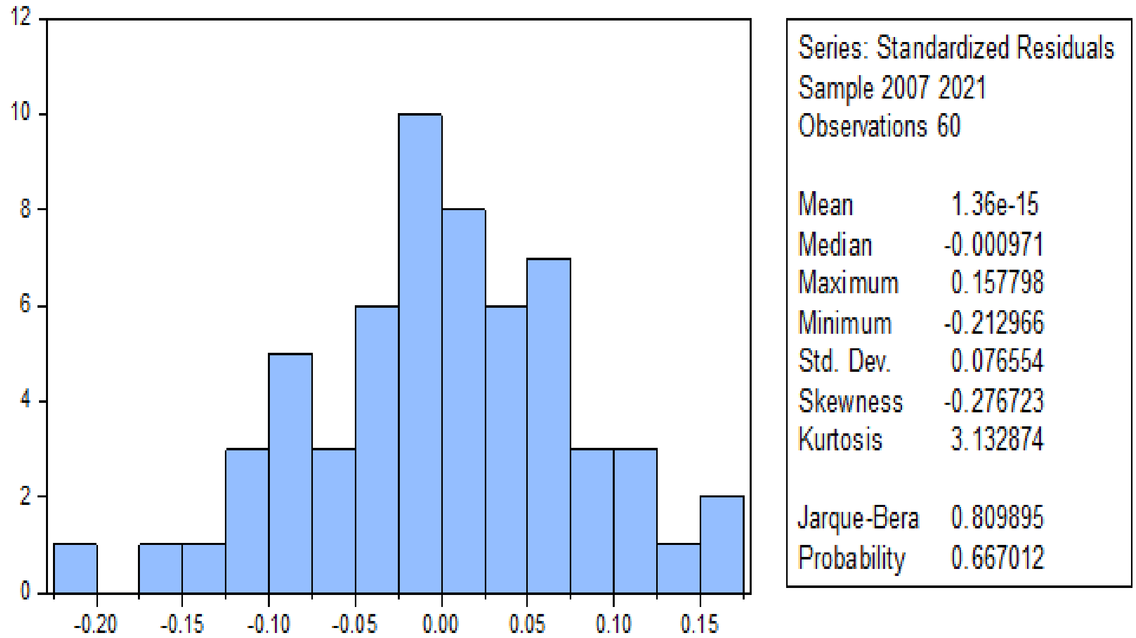

Figure 2: Jacque Berra Normality Test

Source: computed by authors

Overall, it is quite evident the data and variables are normally distributed given the result of Jacque Berra statistics as shown in figure 2. The skewness and kurtosis are both within the value threshold of 0 and 3 respectively showing normal distribution of the variables and data. Also, the null hypothesis of Jacque Berra assumes a normal distribution at 5% significant level. But with a p-value (0.66), which is more than 0.05, we fail to reject the null hypothesis. This means that the variables and data therein are distributed normally, indicating that the model is fit and robust.

Table 6: Correlation Matrix Analysis

Variables	EF	GDP	EC	RDE	IRE
EF	1.000000				
GDP	0.257324	1.000000			
EC	0.433281	-0.404615	1.000000		
RDE	-0.507646	-0.548182	-0.270419	1.000000	
IRE	-0.721746	-0.321338	-0.696097	0.744507	1.000000

Source: computed by authors

The correlation matrix adopted for the study was used to establish how strongly variables in the model are correlated. Thus, a higher correlation coefficient ($r2 \geq 0.8$) shows strong multicollinearity among the variables. Table 6 show that variables such as EC, RDE, IRE, and GDP have weak correlation with the outcome variable (EF). This indicates a weak case of multicollinearity in the estimated model.

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Table 7: Result of Cross Section Dependence Test

Variables	Brusche Pagan LM	Pesaran Scaled LM	Pesaran CD
EF	0.9944	0.0073	0.5518
GDP	0.9925	0.0078	0.9069
RDE	0.4312	0.24	0.3771
EC	0.8502	0.0341	0.5978
IRE	0.7433	0.0608	0.191

Source: computed by authors

In the literature, CSD has become one of the primaries focuses of econometric evaluation with significant impact (Ahmed et al. 2022). Essentially, CSD assumes the null hypothesis that there is no cross-section dependence amongst the variables in the model. Thus, if the p-values of the appropriate Brusche Pagan LM test are greater than 0.05 level of significance, the null hypothesis will be rejected. From table 7, it shows that the p-value is higher than the significant level of 0.05, and thus we fail to reject the null hypothesis. This means that there is no cross-section dependence in the model.

Table 8: Unit Root Tests

Variables	Fisher-ADF	Fisher-PP	LLC	IPS	Integration Level	
					Level	1st difference
EF	27.9 (0.000)	53.9 (0.000)	-3.29 (0.000)	-3.62 (0.000)	-	1(1)
GDP	19.3 (0.013)	54.5 (0.000)	5.39 (1.000)	-2.32 (0.010)	-	1(1)
RDE	24.9 (0.000)	43.3 (0.000)	-2.05 (0.019)	-3.19 (0.000)	-	1(1)
EC	25.0 (0.001)	34.5 (0.000)	4.70 (0.000)	-3.18 (0.000)	-	1(1)
IRE	18.2 (0.019)	44.2 (0.000)	-4.03(0.000)	-2.05(0.015)	1(0)	-

Source: computed by authors

Table 8 result of the Fisher-ADF, Fisher-PP, LLC, and IPS show that ecological footprint, research and development, Gross Domestic Product and energy consumption has a unit root at level and thus not stationary. Renewable energy was the only variable that was stationary and integrated at level 1(0) without a unit root. But at first difference however, the other variables became stationary without a unit root and are integrated accordingly at 1(1).

4.2. Pedroni Co-integration Test Result

After checking for unit root and testing for stationarity, the authors went further to check for co-integration possibilities amongst the variables in the model. In this regard, two panel co-integration tests were done using Pedroni (2004) and Kao (1999) to check for possible long run relationship amongst the variables and cross sectionally in the MINT grouping and within the period time. The Pedroni test was adopted to avoid ambiguity, while the Kao test was used to check the robustness of the long run relationship in the model between ecological footprints, gross domestic product, investment in renewable energy, energy consumption, and research and development expenditure.

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Table 9: Co-integration Test Result

Variables	Pedroni Co-integration Test							Kao (1999) Test
	Within-Dimension				Between-Dimension			Robust Check
	Panel (v-stat)	Panel (rho-stat)	Panel (PP-stat)	Panel (ADF-stat)	Group (rho-stat)	Group (PP-stat)	Group (ADF-stat)	ADF-statistics
EF	0.70 (0241)	0.60 (0.728)	-5.65 (0.000)	-1.67 (0.047)	1.95 (0.974)	7.35 (0.000)	-0.75 (0.223)	-1.915 (0.027)
EC	-1.53 (0.935)	-0.00 (0.496)	-1.87 (0.030)	-1.48 (0.068)	1.29 (0.902)	-2.81 (0.002)	-1.49 (0.067)	-1.630 (0.051)
GDP	-1.14 (0.874)	0.95 (0.831)	-0.62 (0.267)	-1.10 (0.509)	1.03 (0.848)	-5.10 (0.000)	-0.03 (0.487)	0.129 (0.448)
RDE	-0.68 (0.753)	0.69 (0.332)	-3.25 (0.000)	0.27 (0.334)	0.36 (0.644)	-3.55 (0.000)	0.81 (0.791)	-3.000 (0.001)
IRE	0.36 (0.357)	1.35 (0.911)	-1.59 (0.015)	-2.48 (0.006)	2.20 (0.986)	-2.31 (0.010)	-1.92 (0.027)	-2.351 (0.009)

Source: computed by authors

Instructively, there are seven tests within the Pedroni (2004) variant of co-integration test, separated into between and within group dimensions. Essentially, four outputs were obtained in the within group dimension. These are: panels PP-state, ADF-stat, Rho-stat, and V-stat. The outputs generated in the between group dimension are: groups Rho-stat, PP-stat, and ADF stats respectively. The "between group" identifies the long-term correlation between variables, while the "within group" dimension focuses on the long run relationships amongst variables in the panel data (Manasseh et al. 2024). Consequently, if the p-value of any of the stats is less than 0.05, then there is co-integration. In the light of this, and as shown in table 9, the Philip Peron (PP) Panel statistics all have a p-value that is less than 0.05 for the variables, with the exception of GDP. This shows that the variables are co-integrated in the "between-dimension" columns and that they move in tandem through time, regardless of occasional oscillation or fluctuations amongst the MINT countries. Likewise, the PP-stat in the "within dimension" group equally shows a strong long-term co-integration amongst variables and a long-term relationship amongst the MINT countries. This reveals that the panel variables in the model shows a stochastic behaviour, leading to the assumption that there is an equilibrium long run relationship between them. Just like the PP-stat, the Kao (1999) tests also shows a co-integration of the variables with a p-value less 0.05, except for GDP as well. In this regard, the null hypothesis that there is no co-integration is hereby rejected.

4.3. Fixed Effect Model (see table 4) and Fully Modified Ordinary Least Squares (FMOLS)

After establishing the presence of co-integration in the model, the FMOLS method for co-integrating heterogeneous panel like ours was estimated to check the long run equilibrium relationship in the model between the variables (Pedroni, 2000). Also, the FEM test result in table 4 accounted for the individual specific effects of both the cross-sectional units and time periods in the model as a result of its heterogeneous nature, which OLS could not account for. In this regard, table 4 FEM test result showed that FEM is a good fit for the model as the R^2 (coefficient of determination) value of 0.993 shows a high explanatory

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power and effect of the combined independent variables (EC, GDP, IRE, and RDE) on the dependent variable (EF). In essence, what this shows is that the independent variables confidently explain changes in the dependent variable by 99.3%, while the remaining 1.7% were caused by other factors not related to the independent variables.

Table 10: FMOLS Test Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
EC	-2.055680	0.012629	-162.7772	0.0000
GDP	-0.211994	0.010626	-19.95137	0.0000
IRE	3.381442	0.015939	212.1469	0.0000
RDE	5.606118	0.015603	359.2984	0.0000

Source: computed by authors

Table 10 shows the FMOLS results which reveals a statistically significant value for all the variables examined at 5% level of significance. The result shows that for every unit change in Energy Consumption (EC) and GDP, there is a long run coefficient of -2.055- and -0.211-unit changes in Ecological Footprint in the MINT countries under study. This means that there is a negative significant impact of EC and GDP on EF. It also shows that as EC continues unsustainably and GDP continues to rise as a result of unsustainable industrial practices, it will lead to a negative impact on EF. On the other hand, every unit change in Investment in Renewable Energy (IRE) and Research and Development Expenditure (RDE), there is a long run coefficient of 3.381- and 5.606-unit changes on EF. The positive significant impact of IRE and RDE on EF shows that IRE and RDE which stand as proxies for green finance and financial innovation significantly helped to reduce the emission of CO2 through investments in eco-friendly businesses on one hand and mitigated the effects of emissions on the other hand by funding green technologies in that regard.

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study examined the impact of green finance and financial innovation on environmental sustainability, with conclusion from the estimated result that there is a long run equilibrium relationship between EF, EC, GDP, IRE and RDE within the MINT countries. The major findings of the study are that there is a negative significant impact of incremental energy consumption in on environmental sustainability, especially if this was done in an unsustainable manner in the MINT countries.

Also, as energy consumption increases, so will industrially output with carbon emissions, leading to increased GDP which equally shows a negative significant impact on environmental sustainability proxied by EF. For instance, figure 1 shows the graphical presentation of the variables manifestation in the MINT countries shows that Mexico has the highest energy consumption of 1800 Kg oil per capita, while Nigeria has the lowest with about 800 Kg oil per capita in 2020 within the MINT country grouping. If this trend

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continues unchecked, the negative impact will also increase, with devastating consequences for the environment. Furthermore, according to the findings above, it is evident that green finance and financial innovation in countries groupings like the MINT economies has the potential to impact environmental sustainability positively as shown in table 10.

For context, green finance entails the mobilization of funds and investment in renewable energy (IRE) such as hydropower, wind and solar, as well as in research and development (RDE) in green technologies that can build clean energy infrastructures that promotes economic growth and development without impacting the environment negatively. In view of this, there will be better air quality and less dependency on fossil fuels and limited greenhouse gas pollution.

Cross sectionally, the trend in figure 1 equally shows that Nigeria made positive stride in financial innovation and green finance through IRE and RDE compared to others in MINT grouping. This also correlates with its low energy consumption and emission within the group compared to others.

This finding does not support the EKC theory given the fact that economically better off countries with relatively income per capita like Indonesia and Mexico failed to use their economic growth rates and developmental strides to encourage green finance and financial innovation as represented by IRE and RDE.

Conversely, Nigeria with a relatively poor economic standing is the country with a better financial innovation and green finance, which does not align with the EKC thesis which states that as economies improve it invests in green technologies that will foster an eco-friendly business and economic environment to protect the environment from degradation.

5.2 Policy Implications and Recommendations

Based on the foregoing, the study makes the following recommendations and policy prescriptions to the MINT economies. First there is need for a concrete assessment of the ecological footprint of the MINT countries that will help framework a sound and effective climatic and environmental policy that will address their ecological challenges and needs. Second, there has to be a strong investment in renewable energy, as well as in research and development to help combat adverse ecological footprint within MINT countries that might lead to environmental deterioration.

There should also be strong regulatory framework within the MINT countries that will drive green finance and financial innovation initiatives that will make available financial instruments such as green bonds, green investments, green loans and funds, etc.

This will aid the direction of finance to business ideas and initiatives that are eco-friendly, and away from those that are destructive to the environment. Finally, strict environmental regulations and legislations must be promoted to reduce and deter harmful environmental practices within the MINT countries.

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