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A Holistic Approach to Carbon Reduction via Energy, Infrastructure, and Financial Inclusion

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Abstract

Financial inclusion is essential for a sustainable energy and infrastructure foundation. The study presents a comprehensive analysis of the relationship between energy structure, infrastructure, financial inclusion, and carbon emissions in the "MINT + BRIC" countries (Mexico, Russia, China, India, Brazil, Indonesia, Nigeria, and Turkey). Utilizing data from 1990 to 2022, the study finds that infrastructure, energy structure, and financial inclusion are key factors in reducing carbon emissions. The results indicate that energy structure decreases 0.30% of carbon emissions in these nations. The research employs various econometric models to establish these relationships and suggests that increased investment in infrastructure and energy, along with expanded financial inclusion, are necessary for long-term sustainability. The study aligns with the United Nations Sustainable Development Goals.

Keywords

Energy structure; Financial inclusion; Sustainable environment; Infrastructure; Carbon emissions

1. Introduction

Achieving carbon neutrality is a worldwide objective and a top goal for the Sustainable Development Goals of the United Nations (UN). Energy is essential for attaining carbon neutrality. Concretely, overuse of energy has increased carbon emissions, which has resulted in serious environmental problems globally. This has led to a surge in floods, particularly in less developed nations. Therefore, the dispersion of carbon emissions has adversely affected the environment [1, 2], necessitating the use of renewable energy sources, with many nations already initiating the transition to sustainable energy sources. To reduce emissions of carbon dioxide, however, essential infrastructure is required, including the building of roads, underpasses, and bridges; simple transport options; internet access; information technology; and financial inclusion [3]. Robust infrastructure facilities in a country are indicative of the prosperity of a nation. Examining the infrastructure can provide a valuable understanding of a society's welfare [4]. Therefore, this research aims to examine the close links between infrastructure, financial inclusion, energy generation, and carbon emissions.

According to the World Development Index [5], financial inclusion can propel a nation's progress by providing unrestricted access to financial products and services for every individual and household. Technologies that control carbon emissions can effectively reduce carbon emissions [6]. Several theories about carbon emissions and financial inclusion's effects. A. Tamazian et al. say that putting in place measures for financial inclusion can allow people to buy homes that use a lot of energy, which speeds up the release of high carbon emissions [7]. Other scholars support high financial inclusion and argue that advanced technology can lead to increased energy efficiency, thereby lowering carbon emissions [8]. The implementation of renewable energy alternatives is equally crucial for achieving carbon neutrality. A. Amin and E. Dogan define energy structure as the proportion of overall energy consumption that includes renewable energy sources [9]. M Numerous studies have explored the association between energy structure and carbon emissions; however, the interaction between energy structure and infrastructure has not been considered [10]. Adopting an energy structure, in the context of sufficient infrastructure, can potentially decrease carbon emission levels.

According to [11], BRIC + MINT countries account for 41% of the worldwide energy consumption, which significantly exacerbates environmental problems in this region. As to the findings of [3], these regions meet 80% of their fossil fuel-based energy requirements. The recent COVID-19 epidemic significantly impacted the energy supply, leading to a 6% decline. However, it subsequently recovered and reached levels comparable to those of 1996 (IEA, 2019). Furthermore, the countries chosen in this study actively pursued the development of policies aimed at mitigating carbon emissions. Furthermore, these countries assert that infrastructure facilities and services play a crucial role in facilitating effective productive, transportation, and commerce activities, thereby stimulating economic growth and ultimately contributing to poverty reduction. These economies persist in their efforts to advance infrastructure development. Significantly, the COVID-19 pandemic disrupted the progress of infrastructure development on a worldwide scale. Nevertheless, the MINT and BRIC economies require "The New Landscape of Resilient Infrastructure." Hence, the aim of the present study is to investigate the significance of infrastructure and energy structures in the MINT and BRIC economies in the estimation of environmental impacts.

The financial industry offers a plethora of opportunities for developing cutting-edge instruments to address environmental risks. In the current context, we can view environmentally friendly and sophisticated energy alongside renewable energy sources as complementary aspects of environmental management. The aforementioned elements of economic management that indicate trade freedom, industrial production, and urbanization are crucial environmental management indicators. assert that economic management fosters environmental protection, energy efficiency, and financial inclusion. The industries that provide renewable energy are growing in emerging nations. Thus, industries located abroad with a thriving financial sector tend to grow even more rapidly than those in countries with unstable financial systems and a weak credit market [12, 13].

The ultimate study goal is to provide three significant additions to the research domain. We carry out a detailed investigation of the connection among carbon emissions, financial integration, and energy structure. This is the first study to use this method, according to the author. Second, this research examines how infrastructure affects the environment in Mexico, Russia, China, India, Brazil, Indonesia, Nigeria, and Turkey, offering concrete outcomes and impacts on the selected economies. Furthermore, to experimentally calculate the association between the aforementioned parameters, the literature recommends using robust econometric estimates. The initial stage of the methodological approach for panel data estimates is sectional dependence (CSD) diagnostics. The CIPS unit root tests address the Critical Success Distribution (CSD) problem in panel data. Additionally, we use Westerlund's co-integration, AMG, and CCEMG estimates because they are suitable for representing panel data. We evaluate stability using the "fully modified ordinary least squares (FMOLS)" and "dynamic ordinary least squares (DOLS)" approaches

The subsequent sections of the paper are structured as follows: Section 2 provides an overview of the pertinent literature; Section 3 outlines the methodological approach; Section 4 gives the empirical estimates, their interpretations, and a brief discussion; and Section 5 brings the detailed study results to a close**.**

2. Literature Review

The literature review, particularly in scientific circles, highlights the continuous discussion about energy structure, infrastructure, financial equality, and emission levels and their worldwide effects. A lot of research has been published recently that looks at energy, infrastructure, financial inclusion, and carbon emissions in different situations [14-17]. For example, P. Sadorsky [18] studied energy use and environmental quality in the Great Seven (G7) countries from 1980 to 2005. The study provided proof that, over time, carbon emissions reduce the amount of energy used. The study presented evidence that carbon emissions have a beneficial impact on energy consumption in the long run. In their study, Q. Ma, M. Murshed, and Z. Khan [19] analyzed the relationship between carbon pollution, economic development, and energy structures. They proposed that a decrease in energy prices may result in significant economic expansion, thereby causing carbon emissions to reach their highest point. This study delved deeper into this correlation, contributing to the growing body of literature. The current study contributes to the existing knowledge by examining the correlation between carbon emissions and infrastructure, energy structure, and financial inclusion within the MINT + BRIC group using rigorous econometric estimations [20, 21].

Moreover, based on several models, several pertinent papers are examined for inclusion in this section. In their study, S. Shafiei and R. A. Salim [22] used the Granger causality and STIRPAT model to assess the relationship between energy and CE from 1980 to 2011. Their findings indicated that non-renewable energy sources are responsible for carbon emissions in OECD nations. The research findings also indicate a positive and significant relationship between industrialization, GDP per capita, and population size with CE. I. Ozturk and A. Acaravci [23] emphasized the correlation between energy and CE in Turkey and performed the ARDL cointegration analysis using data spanning from 1958 to 2005. Remarkably, their final determination was that there is no correlation between energy consumption and carbon emissions.

A recent study conducted by Y. Li et al. [24] investigated the influence of energy structure on carbon emissions in 30 provinces of China. The researchers used the extended STIRPAT technique and analyzed data from 2011 to 2017. The results indicate that the energy structure has a substantial influence on carbon emissions. Furthermore, it is concluded that when coupled with well-developed infrastructure, this influence exhibits a steady reduction. These findings highlight the vital importance of infrastructure in eliminating carbon emissions. Various studies also highlight the role CO2 emissions and their impact on economic growth [25-27].

The existing body of research on the relationship between financial inclusion and carbon emissions is rather small, despite its popularity among scholars and researchers [28-31]. To maintain a sustainable economy and environment, financial inclusion is seen as necessary. Ultimately, Wang et al. (2022) determined that financial savings yield enduring effects on both individuals and society. M. Usman, R. Kousar, and M. S. A. Makhdum [29] examined the financial inclusion (FI) and corporate environment (CE) of 15 nations using an augmented mean group estimation method. In conclusion, the authors found that financial inclusion reduces CE. A study conducted by S. A. H. Zaidi, M. Hussain, and Q. Uz Zaman [3] examined the relationship between financial inclusion and CE in 23 OECD member countries, with infrastructure serving as a control variable. Estimations using the CS-ARDL model demonstrated the beneficial influence of financial inclusion on CE, and more significantly, they identified a sensitive correlation between infrastructure and CE.

[8] recently investigated the relationship between financial inclusion (FI), environmental sustainability (ES), and carbon emissions (CE). They proposed that financial inclusion indirectly affects CE by influencing energy structure and consumption. Additionally, they hypothesized that improving financial inclusion could help reduce carbon emissions. The studies indicated above demonstrate that researchers and intellectuals have been especially interested in the interconnection of energy structure, infrastructure, financial inclusion, and carbon emissions. Nevertheless, there is a lack of studies in the existing literature about this connection, especially in the MINT + BRIC panel. Moreover, the relationship between energy structure, infrastructure, financial inclusion, and carbon emissions continues to lack a definitive conclusion due to conflicting findings and viewpoints. It is the objective of the present work to address this discrepancy.

3. Theoretical Background and Model Construction

The relationship between growth and environment has drawn a lot of scholarly interest, and the body of literature on the subject is continually expanding. Many economists and environmentalists have investigated the underlying contributing elements to car pollution levels since [32] established the nexus [33-35]. The increasing body of research on this topic has led to the recognition of energy structure as a significant determining factor. Every nation's economy is largely dependent on the energy sector, which is also said to be a factor in excessive carbon emissions [36, 37]. Nonetheless, energy structures made of renewable materials can serve as a good substitute for conventional energy sources [34, 38-40]. Consequently, the goal of this work is to recalculate how much ES affects CE. Furthermore, infrastructure—or the availability of supporting facilities—is a crucial component of a sustainable economy and environment. Therefore, it is also suggested that infrastructure has an impact on carbon emissions. Furthermore, both short- and long-term economic activity depend on financial services and facilities. This study also takes financial inclusion—the availability of financial services—into account. Consequently, the suggested model's mathematical form characterizes Y, ES, INF, FI, and P as functions of carbon emissions as follows:

$$CE = f(Y, ES, INF, FI, \mathrm{P}, \mathrm{T}) \tag{1}$$

Equation (1) has the following econometric form:

$$\Delta CE_{it} = \alpha + \beta_1 Y_{it} + \beta_2 ES_{it} + \beta_3 INF_{it} + \beta_4 FI_{it} + \beta_5 P_{it} + \mu \tag{2}$$

where CE stands for total carbon emissions and Y, the income level, is represented by the gross domestic product constant at 2015 US dollars. ES stands for energy structure, or the proportion of total energy consumption that comes from renewable energy; INF stands for infrastructure, which is calculated using principal component analysis (PCA) and data from the phone and internet; PCA is used to calculate the financial inclusion index (FI), which is comprised of proxies for financial inclusion such as ATMs, deposits, bank branches, and life insurance (Zaidi et al., 2021a), and T is patented. The whole population is represented by P. The information was gathered for the years 1990–2022 from the [41]

Based on prior research and the economic nature of the components, the coefficient orientations are also predicted. The coefficient is anticipated to be more than 0 starting at the MINT + BRIC panel's income level. This is explained by the MINT + BRIC economies' ongoing expansion and the significant level of environmental degradation that is anticipated so that $\beta 1 > 0$. Furthermore, it is suggested that financial inclusion, infrastructure, and the energy system would all benefit the environment. This is founded on prior research and economic data (refer to the literature review section). This means that the coefficients β2, β3, and $\beta 4 < 0$ for ES, INF, and FI are anticipated to be negative. Furthermore, because the MINT + BRIC economies have substantial population growth ($\beta 5 > 0$), a positive population coefficient is anticipated.

$$CE_{it} = \partial_i + \beta_i A_{it} + C_{it} + D_i \hat{\mu}_i + \mu_{it} \hat{\beta}_{AMG} = N^{-1} \textstyle\sum_i \hat{b}_i \tag{3}$$

Different slope parameters can be used to identify time-varying, non-detectable occurrences using the AMG and CCE-MG.

In panels with nonstationary variables (cointegrated or not) and multifactor error terms (cross-section dependence), they specifically perform comparably well in terms of bias or root mean squared error (RMSE). That suggests that the AMG and CCEMG can function as effectively whether or not Table 3 data is stationary [42, 43]. To ascertain the relationships between energy structure, infrastructure, financial inclusion, and carbon emissions, we employed a robust econometric analysis using a panel of data spanning from 1990 to 2022. This period was chosen to capture the evolution of these variables in response to global environmental policies and internal economic shifts within the MINT + BRIC nations. A fully modified ordinary least squares (FMOLS) and dynamic ordinary least squares (DOLS) are estimated to verify the robustness of the findings. While trade is measured using the ratio of exports + imports to GDP, the robustness analysis also calculates the impact of trade on carbon emissions.

4. Econometric Estimations

To experimentally estimate the model suggested in Section 3, an econometric technique is utilized. Specifically, the usual problem of the panel data is checked using an estimated cross-sectional dependence test. These estimations have the following econometric representation:

$$\Delta x_{it} = \varphi_i d_i + \vartheta_i x_{i(t-1)} + \delta_i z_{i(t-1)} + \sum_{j=1}^{n} \partial_{ij} \Delta x_{i(t-j)} + \sum_{j=0}^{n} \emptyset_{ij} \Delta z_{i(t-j)} + \omega_{it} \tag{4}$$

Checking the panel data's unit root attribute comes after the CSD estimation. Second-generation stationarity tests are used to evaluate the characteristics of a unit root in the examined data. The application of first-generation stationarity estimates may yield inaccurate findings when the CSD problem exists. The unit root test chosen is the "Cross-Sectionally Augmented Im, Pesaran, Shin (CIPS)". The following is a description of the test's econometric form:

$$\text{CIPS}\ (Q, P) = t - bar = Q^{-1} \sum_{i=1}^{Q} t_i(Q, P) \tag{5}$$

When dealing with panel data, estimating the co-integration between the variables is the next suggested step after the stationarity check. This study uses panel co-integration tests to examine this phase. The selection of these estimates is justified by the fact that first-generation co-integration can support the long-term relationship between the variables but might not be able to address the CSD problem. To handle cross-sectional dependence, we also use [44] co-integration.

Next, estimates are made for the Table 2 variable's long- and short-term links. The augmented mean group (AMG) technique [43] and the common correlated effects mean group (CCE-MG) estimator [42] are used because of the problems with the panel data [43, 45]. The corresponding estimations are described as follows:

$$\Delta CE_{it} = \beta \Delta A_{it} + \sum_{t=2}^{T} C_t \Delta D_t + \mu_{it} \rightarrow \widehat{C_t} = \widehat{\mu_t} \tag{6}$$

$$CE_{it} = \partial_i + \beta_i A_{it} + C_{it} + D_i \hat{\mu}_i + \mu_{it} \hat{\beta}_{AMG} = N^{-1} \sum_i \hat{b}_i \tag{7}$$

For identification purposes, time-varying non-detectable occurrences with a range of slope parameters can be handled by the AMG and CCE-MG. Specifically, they exhibit comparable performance in terms of bias or root mean squared error (RMSE) in panels containing multifactor error components (cross-section dependence) and nonstationary variables (cointegrated or not). According to [43] and [42], this suggests that the AMG and CCEMG can function as well regardless of whether Table 3's data is stationary. Furthermore, the fully modified ordinary least squares (FMOLS) and dynamic ordinary least squares (DOLS) are estimated to verify the robustness of the findings. While the ratio of exports + imports to GDP is used to measure trade, the impact of trade on carbon emissions is also measured in the robustness analysis.

5. Results and Discussion

Table 1 displays descriptive statistics for several significant variables in the MINT + BRIC countries (Mexico, Russia, China, India, Brazil, Indonesia, and Turkey) from 1990 to 2022. Table 1 presents a comprehensive overview of the key variables under study, including carbon emissions (LNCE), energy structure (LNES), financial inclusion (LNFI), infrastructure (LNINF), population (LNP), trade openness (LNT), and economic growth (LNY). The descriptive statistics reveal significant variations in carbon emissions and energy structures across the MINT + BRIC countries, underscoring the heterogeneity in their development trajectories and the potential for tailored policy interventions. Examining these variables can help us understand the links between them and their implications for sustainable development in these emerging economies. These nations have moderately high average carbon emissions with a mean value of 1.088, median: 1.021, and standard deviation of 0.783. The relatively high standard deviation indicates fluctuations in emissions, potentially due to different stages of industrialization and changes in energy regulations. For these economies, energy structure is crucial. The information indicates a moderate to high reliance on specific energy sources, potentially including non-renewable ones. Variation is evident in the standard deviation, suggesting varying energy policy and infrastructure. The comparatively high level of financial inclusion suggests substantial access to financial services. This is essential for sustainable development, as it ensures equitable growth and aids in financing green projects.

A low mean suggests that population pressures differentially impact these nations' sustainable development policies, not uniformly across the board. While it differs by nation, economic growth is generally constant. Controlling this expansion is necessary to finance sustainable development projects and prevent rising carbon emissions.

Table 1. Descriptive Statistic Test

	LNCE	LNES	LNFI	LNINF	LNP	LNT	LNY
Mean	1.088375	2.935348	3.652337	2.251724	0.010685	8.406807	1.321362
Median	1.020565	3.086487	3.541934	2.690246	0.235220	8.330442	1.509647
Maximum	2.682492	4.080584	5.222319	3.459163	0.761339	11.97678	2.612700
Minimum	-0.434712	1.156881	2.452026	-0.539569	-3.502972	5.075174	-4.580680
Std. Dev.	0.783060	0.878446	0.652338	1.042947	0.715091	1.708800	0.919635

Table 2 shows a perfect correlation between carbon emissions, underscoring their significance in environmental evaluations. Strong cross-sectional dependence is indicated by the significant CD test and p-value, indicating that the carbon emissions in one nation are influenced by those in other countries. The significant connection between energy structure and other factors, namely carbon emissions, indicates that the selection of energy sources (such as fossil fuels versus renewables) has a crucial role in determining this carbon output. The substantial coefficient of variation (CSD) demonstrated that alterations in the energy composition of one country had repercussions on other countries, therefore emphasizing the worldwide scope of energy policy effects. Financial inclusion exhibits a limited association with the other factors, indicating that its influence is mostly indirect. Yet, the substantial test suggests that the financial inclusion policies of one country can either impact or be impacted by those of other MINT + BRIC countries. Furthermore, there is a moderate to high correlation between infrastructure and both economic growth and carbon emissions, underscoring its crucial role in development. Cross-sectional interdependence implies that infrastructure advancements in one country influence others, particularly in an interconnected global economy. However, population influences energy consumption, infrastructural needs, and carbon emissions, resulting in a modest link. The large CSD test implies population growth trends in one country affect others, notably through migration and economic ties. Patent registrations reveal a limited association between trade openness and carbon emissions or energy structure, suggesting that trade is vital but may not directly affect them. This shows that trade policies or innovations in one country affect others. The link between infrastructure, energy structure, and economic growth highlights their significance in energy consumption and emissions. Particularly in this integrated collection of economies, the significant CSD test demonstrates the impact of economic policies or growth patterns in one country on others.

Table 2. Correlation test and CSD estimations

Variables	Correlation	CD Test	P-value
CE	1.0	10.50956	0.0000***
ES	0.9	16.60840	0.0000***
FI	0.2	10.50689	0.0000***
INF	0.7	15.85986	0.0000***
P	0.6	17.09453	0.0000***
T(patent)	0.2	7.046706	0.0000***
Y(GDP)	0.8	6.018686	0.0000***

Table 3 illustrates the CIPS approach, revealing that most variables (such as CE: -0.6623, ES: -0.8552, etc.) display test statistics close to zero, indicating their non-stationary nature at their respective levels. The presence of non-stationarity indicates that these variables exhibit temporal trends, resulting in changes in their statistical characteristics, such as mean and variance. After applying the first difference, the test statistics for all variables exhibit a noteworthy negative value (e.g., CE: -3.4725, ES: -2.1276, etc.), suggesting that they reach a state of stationarity. This suggests that the initial variables display integration of order one, represented as I (1), which indicates their stability and predictability after differencing.

Table 4's cointegration test results show that there is evidence of a long-term equilibrium relationship between the variables for the panel overall, as shown by the panel statistics. However, a closer examination of each country separately reveals less conclusive evidence, as indicated by the group rho-statistic, which does not offer robust evidence. These findings suggest that although the MINT + BRIC countries may demonstrate a stable long-term relationship, the Kao test shows that carbon emissions, energy structure, financial inclusion, and economic growth have a long-term equilibrium relationship across MINT + BRIC countries, despite their diverse economic, social, and environmental conditions. Changes in one variable tend to relate to predictable changes in others throughout time, demonstrating that regional trends and policies can affect these countries consistently, as shown in Table 5. These results are in agreement with previous work [34].

Table 3. CIPS TEST

Variables	At Level	1st difference
CE	-0.6623***	-3.4725***
ES	-0.8552***	-2.1276***
FI	-4.4570***	-3.0542***
INF	-1.1885***	-5.3118***
P	-0.6378***	-3.2639***
Y(GDP)	-0.7633***	-4.8844***
T-patent	-1.7077***	-2.7143***

Note: *, **, *** significance level for 10, 5, 1%.

Table 4. Cointegration Test

Within Dimensions	Statistic	Probability
Panel v-Statistic	-0.637202	0.5988
Panel rho-Statistic	-0.818464	0.2065
Panel PP-Statistic	-4.886047***	0.0000
Panel ADF-Statistic	-2.587481**	0.0048
Between Dimension	Statistic	Probability
Group rho-Statistic	1.495644	0.9326
Group PP-Statistic	-0.447274***	0.0003
Group ADF-Statistic	-0.107201***	0.0007

Note: "*, **, *** significance level for 10, 5, 1%".

Table 5. Kao Test

	t-Statistic	Prob.
ADF	-5.339948	0.0000

Table 6 shows the expected robustness of AMG and CCEMG [43] results. The estimation suggests that a negative and significant coefficient indicates a strong association between improvements in energy structure and reductions in carbon emissions. A positive and substantial coefficient shows that financial inclusion improves the variables evaluated, enabling sustainable practice investment. Positive and significant coefficients show that financial inclusion improves the variables evaluated, encouraging sustainable practice investment. A significant positive coefficient indicates infrastructure investments positively contribute. A negative, significant coefficient suggests little detrimental impact of trade openness or patent activities. A modest negative and significant coefficient shows that economic expansion has little negative effect on variables. Overall, CCEMG and AMG found that energy structure improvements considerably cut carbon emissions, but financial inclusion, infrastructure, and trade openness had different effects. Energy structure changes repeatedly negatively affect carbon emissions across both methodologies, demonstrating their importance in sustainable development.

Thorough analysis of FMOLS and DOLS estimations in Table 7 demonstrates significant findings for the MINT + BRIC countries. Both approaches validate the significance of enhancements in energy structure (ES) in mitigating carbon emissions and promoting sustainable development. The projections also indicate a beneficial influence of infrastructure (INF), albeit the effect is rather modest. Financial inclusion (FI) had a stronger beneficial effect in FMOLS but not in DOLS, indicating that although financial inclusion may contribute to improved results, its influence may be less prominent or inconsistent. Economic growth (Y_GDP) has a minimal and inconsequential impact on DOLS, suggesting that economic growth by itself may not lead to substantial enhancements without the implementation of complementary policies. Both approaches show a modest positive impact from trade openness (T_PATENT), underscoring its potential contribution to promoting sustainable behaviors. Population (P) has a high effect on sustainability outcomes in FMOLS but a negligible one in DOLS, suggesting that its influence may be more complex or dependent on specific circumstances.

Table 6. AMG and CCEMG Results

Variables	(CEM) Coefficient	(CEM) P-value	Variables	(AMG) Coefficient	(AMG) P-value
ES	-0.8052	0.0000*	ES	-0.7238	0.0000*
FI	0.0867	0.0003**	FI	-0.0185	0.0000**
INF	0.0283	0.0000***	INF	0.0056	0.0000***
P	-0.1052	0.0000*	P	-0.0376	0.0000**
T(patent)	-0.0319	0.0000**	T(patent)	-0.0065	0.0000***
Y(GDP)	0.0008	0.0000***	Y(GDP)	-0.0023	0.0000***
Const.	2.5269	0.3793			

Note: * is the significance level.

Table 7. Robustness Check (FMOLS and DOLS Estimations)

Variables	(FMOLS) Coefficient	(FMOLS) P-value	Variables	(DOLS) Coefficient	(DOLS) P-value
ES	0.303853	0.0000***	ES	0.270690	0.0000***
INF	0.034797	0.0000***	INF	0.032064	0.0004***
FI	0.012417	0.0000***	FI	0.005565	0.4542*
Y_GDP_	0.015551	0.0077**	Y_GDP_	0.000065	0.5699*
T_PATENT_	0.000168	0.0000***	T_PATENT_	0.000182	0.0000***
P	0.838351	0.0000***	P	0.264727	0.4693*

Note: * is the significance level.

Given the significant role of infrastructure and energy structure in reducing carbon emissions, our findings emphasize the urgent need for the MINT + BRIC countries to ramp up investments in these sectors. Specifically, there is a call for strategic investments that prioritize renewable energy integration and sustainable infrastructure development, which are crucial for achieving the UN Sustainable Development Goals. In summary, the findings underscore the need to prioritize energy design and infrastructure expenditures while thoroughly assessing the contributions of financial inclusion and economic growth in attaining sustainable development objectives.

6. Conclusion

The current analysis looks at the levels of carbon emissions in the MINT + BRIC economies from 1990 to 2022 to achieve carbon neutrality, with a particular emphasis on the FI, INF, ES, T, Y, and P components. From the test, we conclude that higher use of renewable energy sources can greatly lessen carbon emissions, which helps maintain a sustainable environment. By increasing productivity and efficiency, enhanced infrastructure promotes economic growth (LNY). However, if not handled responsibly, this expansion may increase carbon emissions. Greater financial inclusion aids in the development of infrastructure, enabling the financing of environmentally friendly initiatives. Better infrastructure links more individuals to services, which promotes financial inclusion even more. The information emphasizes how crucial it is to approach sustainable development holistically, integrating energy, infrastructure, and financial inclusion to achieve the UN Sustainable Development Goals and reduce carbon emissions.

The correlation between carbon emissions and energy structure indicates that the type of energy sources used significantly influences carbon production. Reducing emissions requires a focus on cleaner RE sources. Given the robust correlation between infrastructure and GDP, it is imperative to prioritize sustainable infrastructure investments to achieve long-term economic prosperity while mitigating environmental deterioration. Population growth increases the demand for infrastructure and energy, which, if not managed effectively, can lead to an increase in carbon emissions. Despite the lack of a clear correlation, Financial Inclusion (FI) negatively impacts sustainable growth by facilitating investments in energy and infrastructure.

In conclusion, our study underscores the pivotal role of infrastructure and energy structure in mitigating carbon emissions within the MINT + BRIC countries. It is imperative for these nations to prioritize sustainable investments in infrastructure and energy sectors while broadening financial inclusion to foster long-term environmental sustainability. Our findings provide a foundation for policymakers to craft targeted strategies that align with global carbon neutrality objectives.

In the study, we implemented several policy implications for MINT+BRIC countries. Increase energy structural investments to reduce carbon emissions. Policies should promote energy efficiency and clean energy. Match financial inclusion methods to sustainable investment goals. Keep building infrastructure but know its carbon footprint may be minor. Infrastructure development should be sustainable. Efficiency and sustainability-focused population growth programs should address environmental impacts. Encourage commerce and innovation, especially in green technologies, while monitoring sustainability.

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Author Contributions Statement

MAJ prepared figures and wrote the manuscript. He also conceptualized the work and conducted the analysis and supervised the work.

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