ASIAN BULLETIN OF CONTEMPORARY ISSUES IN ECONOMICS AND FINANCE
Vol. 4. Issue 1 (2024)

ASIAN BULLETIN OF CONTEMPORARY ISSUES IN ECONOMICS AND FINANCE

ISSN (Print): 2959-0000

http://abcief.com/ 10.62019/abcief.v4i1.44 ISSN (online): 2959-0019

Sustainable Growth in Expanded BRICS: Linking Institutional Performance, Digital Governance, and Green Finance to Environmental Impact

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Chronicle

Article history
Received: Feburary 22, 2024
Received in the **revised format:** March 12, 2024
Accepted: April 22, 2024
Available online: April 25, 2024

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Abstract

The main objective of the current study is to examine the impact of institutional performance, digital governance, and green finance on environmental performance within expanded BRICS nations that have undergone expansion. Key findings indicate that enhancing digital governance significantly reduces emissions; therefore, policies should be implemented to fortify digital infrastructure and promote environmentally responsible practices. The study utilized three discrete regression models to analyse the ecological impact and emissions of carbon dioxide and nitrous oxide, providing insights into the primary greenhouse gases contributing to global climate change. In light of the intricate correlation between emissions and institutional performance, it is imperative to develop nuanced policies that effectively reconcile the need to strengthen institutions with environmental concerns. Green financing is a crucial element that advocates for policies that encourage investment in environmentally friendly initiatives and technology and has a net positive impact on emissions reduction. The adoption of sustainable practices is imperative for economic expansion due to the observed correlation between heightened emissions and economic capacity. To decouple environmental degradation from economic expansion, policies should be implemented to support green technologies. In summary, these results provide evidence in favour of a comprehensive policy approach within the BRICS countries, which ought to achieve a harmonious coexistence of environmental conservation and economic advancement, to the advantage of all stakeholders. The current study is carried out to promote environmental sustainability, reduce harmful activities, strengthen institutions for collaborative pollution management, and enforce stringent environmental regulations on foreign direct investment, the expanded BRICS nations should strive to reduce detrimental activities. Placing significant emphasis on the interdependent nature of economic development and its environmental ramifications is of utmost importance.

Keywords: Ecological Footprint, N_2O, Institutional Performance, green finance, Digital governance.

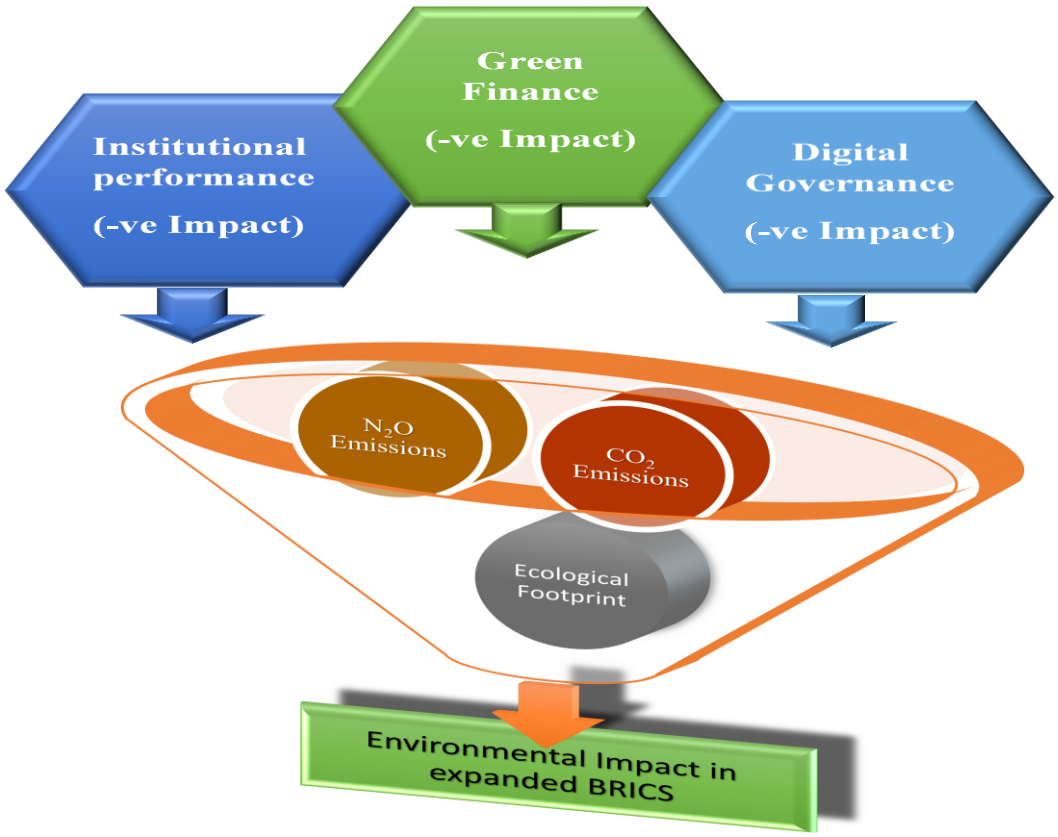

Figure 1.
Graphical Abstract

INTRODUCTION

The Paris Climate Change Agreement was signed in 2015 with the aim of mitigating the effects of climate change on the environment and society. Governments worldwide must implement climate change mitigation strategies. The desired objective is to achieve a temperature increase of 1.5 degrees Celsius above pre-industrial levels. The BRICS nations are causing significant damage to the environment due to their insufficient investment in renewable energy sources and their dependence on a combination of domestic and imported fossil fuels. Environmental degradation (ED) poses a significant challenge to both human survival and sustainable economic development. Excessive utilization of natural resources, such as soil, water, and air, results in the deterioration of the environment. In recent decades, researchers have extensively studied the relevance of ED in various aspects of life and its impact on quality of life, making it a widely researched topic. The sustainability of human life is severely threatened by environmental degradation caused by factors including increasing populations, altering biological conditions, water pollution, greenhouse gas emissions, and global warming. Industrial waste and hazardous emissions are among the limited number of factors that contribute to economic decline (ED) on a worldwide level. The objective of environmental management is to mitigate pollution, greenhouse gas emissions, and this type of waste.

Crucial elements for achieving sustained economic growth over a long period of time consist of allocating resources towards environmentally sustainable initiatives, transitioning towards digitalized governance, and establishing strong and effective institutions. In recent academic studies, there has been significant focus on the impact of governance, political stability, corruption, and the rule of law on environmental quality. The impact of institutional policies and strategies on environmental quality can be significant and beneficial, both directly and indirectly.

Any country or region can facilitate the process of establishing and implementing environmental rules and regulations by adopting a flexible and proactive institutional framework. Businesses, motivated by their goal of maximizing profits, may attempt to bypass regulations in order to achieve higher profits, while capable and reliable institutions with a mission to enhance environments strive to develop and enforce environmental policies efficiently. The presence of a robust institutional framework not only benefits the local population but also has positive effects on neighboring countries, which is referred to as the spillover effect. Kinyua (2023) states that there exist operational and independent organizations that aid in mitigating pollution resulting from economic development. The primary factor behind the low wealth generation in developing economies is their deficient institutional framework. This framework also poses challenges for the development and implementation of environmental policies, the adoption of clean technologies, and the establishment of a sustainable energy infrastructure.

According to Amblard (2021), the relationship between political stability and environmental degradation is contingent upon the level of development. Rich countries with improved institutional frameworks promote foreign direct investment (FDI), leading to a reduction in carbon dioxide (CO_2) emissions due to the technology effect. Foreign direct investment (FDI) has the potential to stimulate economic growth and enhance environmental conditions. However, countries with low income and inadequate institutional factors are less likely to attract FDI. Green finance (GFN) refers to investment strategies that aim to promote environmental improvement and reduce carbon emissions. Green bonds and green credit are the primary sources of funding for green investment vehicles and the mitigation of carbon and greenhouse gas emissions. Compared to regulatory approaches, market-oriented tools such as green bonds and green credit are generally simpler to put into action, more attractive to corporations, and more efficient overall. In order to attract investments from individuals who prioritize environmental concerns, many countries are enhancing their governance, property rights, legal systems, and regulatory frameworks (Ahmed et al., 2023).

Creating trustworthy and transparent organizational environments can help mitigate the risks associated with green investments and attract environmentally conscious investors. Digital governance significantly enhances environmental quality by promoting sustainable practices, reducing paper consumption, and enabling real-time monitoring of environmental conditions. Furthermore, it ensures adherence to regulations and fosters public engagement in conservation endeavors. Bouzguenda et al. (2019) emphasized the significance of digital governance in enhancing environmental quality. To achieve the Sustainable Development Goals (SDGs), Agur et al. (2020) highlighted the importance of digital governance and other practices of vigilant, transparent, and action-oriented leadership. According to experts, digital governance can facilitate economic growth and environmental sustainability by improving communication

between governments, society, and businesses. However, they also mentioned that digitalization can have negative consequences as it can lead to increased energy consumption, which contradicts the objectives of sustainable development. The affordability of digital literacy, education, and infrastructure plays a crucial role in digital governance. The lack of internet access for 2.7 billion individuals further amplifies the inefficiency of digitizing government processes. Shahbaz et al. (2022) argue that in order to achieve social and economic progress while also preserving the environment, it is crucial to prioritize digital governance, industry digitization, and the promotion of renewable energy sources. Guan et al. (2023) propose that sustainable digital governance models aim to achieve a state of equilibrium between economic development and ecological preservation.

Enhancing a country's digital infrastructure, establishing collaborations, and providing incentives can all enhance its global competitiveness. At the beginning of the 2009s, China, Russia, India, and Brazil came together to form a consortium that was referred to as BRIC (see figure 1), which is where the BRICS initiative got its start. The inclusion of South Africa can be seen in Figure 2, which demonstrates that the alliance was strengthened in the year 2010. One of the primary motivating factors behind the formation of this partnership was a response to the shifting dynamics of the global economy. One of the most important motivating factors was the calls for a decision-making process within international financial institutions (IFIs) that was more open and democratic, with a particular emphasis on providing developing and emerging economies with a stronger voice.

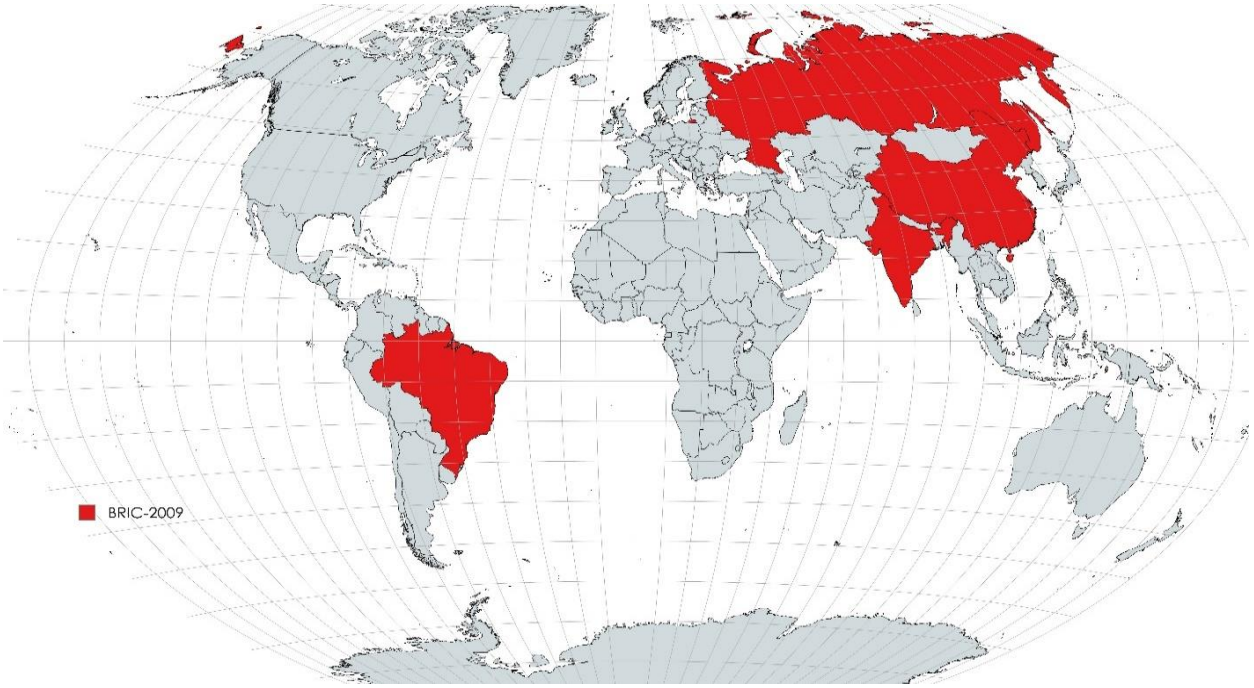

Figure 2.
BRIC

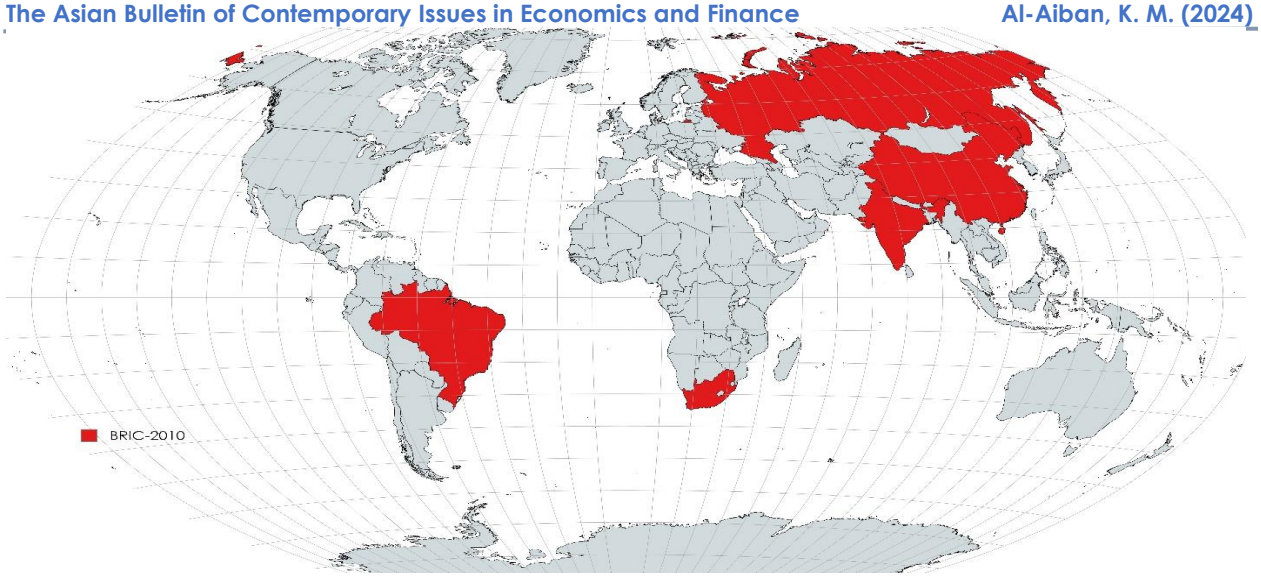

Figure 3.
BRICS

South African President Cyril Ramaphosa made the announcement that the following countries would be joining the BRICS organisation on January 1, 2024. These countries are Argentina, Egypt, Ethiopia, Iran, Saudi Arabia, and the United Arab Emirates. The announcement was made during the 15th BRICS Summit, which took place in August 2023.On January 1, 2024, Egypt, Ethiopia, Iran, and the United Arab Emirates became official members of the bloc (see figure 3). This event took place.

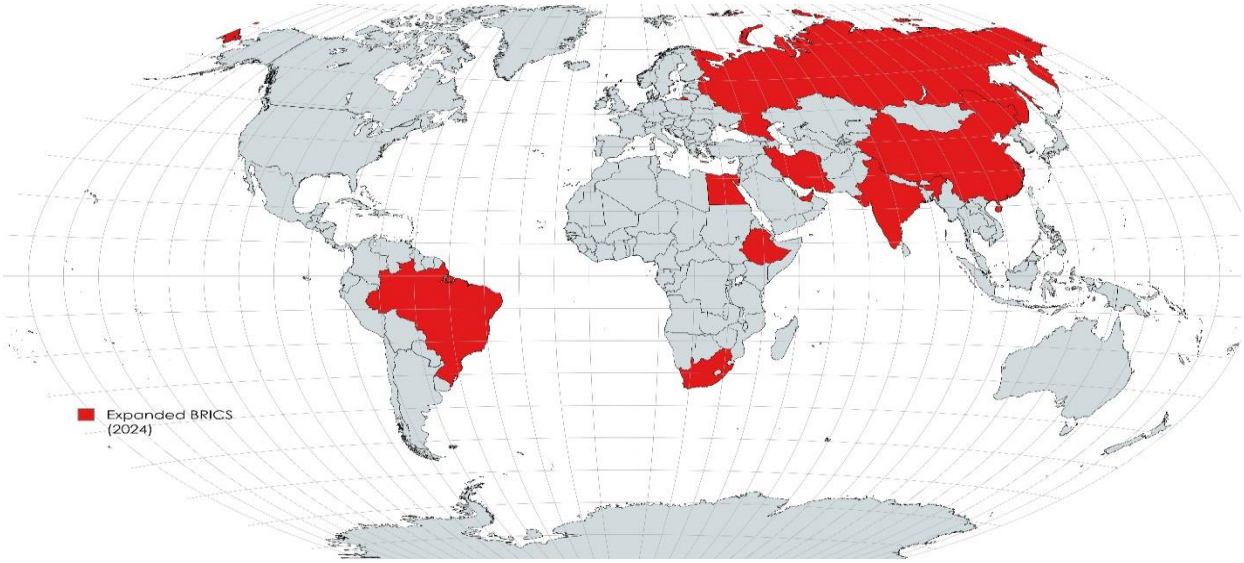

Figure 4.
Expanded BRICS

The primary aim of this study is to examine the correlation between green finance, digital governance, institutional performance, ecological degradation, and the extended BRICS nations. A significant amount of academic research has focused on investigating the relationship between ecological degradation, scientific innovation, and institutional

performance. However, the current academic literature on the expanded BRICS countries is significantly restricted in its coverage (Niemczyk, 2020). This research contributes to the existing body of knowledge in several ways, including the following: 1) Our research employs a newly developed environmental indicator, known as the ecological footprint, along with N2O, to obtain more reliable and accurate results compared to previous studies that evaluated ecological degradation using CO2 measurements.

The main objective of the initial investigation was to create a comprehensive environmental footprint index consisting of six components. (2) The main goal of the initial study was to create an institutional performance index by using twelve quality indicators. Policymakers, social scientists, and the governments of the BRICS countries dedicate significant effort and resources to conducting thorough analyses of their economies (Noomen et al., 2023). The BRICS alliance is preparing to expand its membership to include six more states in early 2024. This development has sparked debates regarding the possible enlargement of the BRICS's burgeoning economic influence. By including more members in the bloc, the total value of goods and services produced within the bloc, known as the gross domestic product (GDP), will surpass $30 trillion. This would make up approximately 29% of the global GDP.

LITERATURE REVIEW

Institutional Performance and Ecological Deterioration

Recent studies by Yan et al. (2023) and Li et al. (2023) have emphasized the significance of robust institutional frameworks in attaining environmental sustainability. These studies have provided insights into the correlation between institutional quality and environmental performance. The findings of this study emphasize the significance of strong institutional frameworks in promoting ecological sustainability, as demonstrated by Ali (2019) and Salman et al. (2019), among other scholarly research. These studies consistently demonstrate the influential and effective role of institutions in implementing and promoting environmentally friendly practices. Allen and McAleer (2020) employed a nonlinear autoregressive distributed lag (NARDL) approach to analyze the data of the G7 countries spanning from 1986 to 2020. A negative and statistically significant correlation was found between the efficiency of their institutions in reducing greenhouse gas emissions.

Consistent with prior research, this study discovered that improving the quality of institutions was the most efficient approach to decrease carbon emissions and advance environmental sustainability. Musili (2023) highlighted the importance of robust financial institutions and systems in sub-Saharan Africa for mitigating environmental degradation. The study conducted by Islam et al. (2023) examined several factors, including internationalization, economic growth, foreign direct investment (FDI), trade openness, and institutional performance, to determine their impact on Bangladesh's CO2 emissions. The study revealed an inverse relationship between carbon dioxide emissions and institutional integrity. Farooq et al. (2023) investigated the relationship between debt and CO_2 emissions in BRICS economies from 1996 to 2018, with institutional efficacy serving as a moderating variable. Studies have demonstrated that nations with lower to moderate income levels are inclined to hold the belief that public debt has an adverse effect on

environmental conditions, while countries with higher income levels tend to hold the opposite view. Shahzad et al. (2021) emphasize the significance of robust government agencies in enforcing environmental regulations to enhance environmental quality and promote sustainable practices. Furthermore, Amblard (2021) asserts that there exists a significant correlation between the effectiveness of institutions and the outcomes of environmental legislation and policy. The study emphasizes the significance of institutions in determining CO_2 emissions, indicating that well-functioning institutions are associated with lower emissions. Cogburn (2019) posits that cultural practices, social norms, and the legal, political, and economic systems collectively influence the functioning of society.

According to Le and Ozturk (2020), a capable organization has the ability to identify and address negative environmental effects, thereby contributing to long-term environmental preservation. To attain environmental advantages, it is imperative to enforce institutional obligations such as safeguarding property rights, promoting unrestricted markets, preserving political neutrality, and upholding the principles of legal governance (McDermott et al., 2023). The presence of law and order, along with effectively implemented regulations enforced by institutions, has a beneficial impact on environmental quality (Zhang et al., 2022). Purcel's (2020) analysis suggests that adhering to legal requirements and implementing effective governance measures could enhance environmental quality and reduce carbon emissions. The study specifically focuses on the influence of governance on CO_2 emissions in developing nations between 2002 and 2016. One potential strategy for reducing carbon emissions is to pursue employment in the service industry.

Haledar and Sethi (2021) conducted an analysis of trends over a 23-year period using data gathered from 101 nations between 1995 and 2017. A statistically significant inverse correlation was observed between environmental quality and institutional quality. Studies conducted in developed nations have demonstrated a negative correlation between increasing carbon dioxide (CO2) emissions and economic growth as measured by Gross Domestic Product (GDP). The environment has experienced positive impacts due to anti-corruption measures and strict adherence to legal principles. The findings not only establish a direct link between carbon dioxide (CO2) emissions and foreign direct investment (FDI) in developed countries, but also highlight the significance of enhancing institutional quality to effectively address and reduce carbon emissions.

Conversely, in developing nations, the situation is the opposite. Riti et al. (2021) conducted a study in 10 countries to investigate the potential correlation between press freedom and efforts to reduce carbon dioxide emissions. The study was informed by press freedom statistics from 1993 to 2016. The study found that there is an inverse U-shaped relationship between per capita GDP and CO_2 emissions. Hence, the study regarded institutional performance as a crucial determinant of CO2 emissions.

Digital governance and Ecological Deterioration

Digital governance is an emerging practice adopted by governments and agencies to oversee, control, and mitigate environmental deterioration. This approach employs advanced techniques such as big data analytics, Geographic Information Systems (GIS), and remote sensing to track and assess the levels of pollution, the decline in biodiversity, and the extent of deforestation. It facilitates the involvement of the public in

environmental conservation and supports the development and execution of policies by promoting well-informed decision-making. The UN General Assembly Resolution 66/2888 highlights the importance of democratic governance, the rule of law, effective administration, and the utilization of technology for the betterment of the general population. The advent of digital technologies presents governments around the world with an unparalleled chance to enhance the quality of life for the general public and attain sustainable development. Digital governance refers to the utilization of information technology by governments and their institutions to enhance governance. This approach brings about advantages such as enhanced service delivery, cost reduction, increased citizen empowerment, expanded interactions with businesses and industry, revenue growth, and improved efficacy and efficiency. Additionally, it enhances economic growth through the enhancement of efficiency in the public sector, the augmentation of demand, and the encouragement of institutional responsiveness and accountability.

By improving the accessibility of crucial services such as healthcare, education, and social welfare, digital governance has the potential to enhance social and environmental sustainability. Open Government Data can be utilized by governments to increase public awareness and understanding of resource management and conservation. This can contribute to the promotion of efforts to combat environmental pollution. Recent research has revealed an inverse correlation between digital governance and carbon emissions, resulting in beneficial outcomes for the environment. Nevertheless, digital governance initiatives that strive to enhance green spaces, emphasize environmental concerns, and implement efficient digital governance have a beneficial impact on environmental sustainability and performance. Enhancing financial development and implementing effective digital governance are crucial in order to decrease carbon dioxide emissions and enhance environmental performance.

Prior research has yielded inconsistent findings, as certain studies have discovered a favorable association between digital governance initiatives and CO2 emissions, while observing adverse correlations with N2O, CH4, and ecological imprint. This study aims to investigate the relationship between digital governance and environmental indicators such as CO2 emission, N2O emission, and ecological footprint in the expanded BRICS countries. By addressing the ambiguity and filling a research gap, the study seeks to provide a clearer understanding of the impact of digital governance on these environmental factors.

Green Finance and Ecological Deterioration

Green finance refers to the deliberate allocation of financial resources with the goal of supporting renewable energy, enhancing energy efficiency, and advocating for environmentally sustainable practices. Research has demonstrated a notable correlation between green finance and environmental performance, underscoring its significance in reducing environmental risks. The research conducted by Tahir et al. (2021) and Zhou et al. (2020) has emphasized the beneficial effects of fiscal decentralization, investment in green technologies, and institutional quality on the promotion of environmental sustainability. Gao et al. (2023) contend that the financial sector plays a substantial role in enhancing environmental quality through its provision of green financial assistance to sustainable businesses and its promotion of environmentally-friendly technology and business strategies.

Green financial development can mitigate domestic carbon dioxide emissions and adversely affect various environmental indicators such as industrial solid waste, wastewater, and nitrogen oxides. Although it does not have a direct impact on the environment, green finance provides support to environmentally friendly businesses and initiatives. Nevertheless, the inclusion of green credit in banks' loan approval processes can restrict the funding abilities of companies that contribute to pollution. Investors are becoming more attracted to green projects that prioritize sustainable development because of the multitude of advantages they offer. Government policies that promote green finance have the capacity to encourage increased investment in the renewable energy industry. Nevertheless, certain scholars maintain viewpoints that diverge from the dominant consensus. For instance, in a study conducted by He et al. (2019a), it was discovered that the expansion of green finance has an adverse impact on the provision of bank loans, impeding the efficacy of investments in renewable energy and causing a negative influence on environmental quality. Existing research predominantly indicates that the progress of green finance will enable the flow of funds into environmentally conscious enterprises and projects. Nevertheless, it does not conclusively establish a direct causal relationship between green finance and alterations in environmental quality.

DATA AND METHODOLOGY

Data

Focusing on digital governance, institutional performance, ecological deterioration, and green finance, this study examined data from BRICS member states from 2000 to 2020. The ecological imprint and emissions of nitrous oxide (N2O) and carbon dioxide (CO2) were examined using three discrete regression models. Because of their status as pollutants and the substantial role they play in accelerating global warming, carbon dioxide and nitrogen oxide have been chosen as environmental indicators (Freire et al., 2023). Because nitrogen oxide emissions are mainly caused by carbon dioxide and methane, it is important to use more than one proxy to capture environmental degradation in order to get a full picture of the environmental impacts in our sample countries. An additional tool for measuring environmental health that takes biological and ecological factors into account is the ecological footprint, which has been incorporated into the study. Allocating funds to environmental sustainability initiatives, or "green finance," has far-reaching effects on both the economy and the environment.

It is critical for institutions to be open, efficient, and effective when implementing policies. The purpose of this research is to evaluate how digital governance has changed the way policies are made and how it can influence innovation and governance to better environmental outcomes. Furthermore, it investigates the link between environmental quality and economic growth in an effort to decipher the economic development's effect on the environment. Missing values in a panel dataset covering the years 2000–2020 are estimated using a variety of methods in this study. The research specifically follows a methodology put out by Rubin, which has been used in this specific study before. Previous research has heavily relied on tried-and-true methodologies, such as GMM, fixed effects, and random effects, to examine the relevance of cross-sectional dependence.

MEASUREMENT OF VARIABLES

The study utilizes Principal Component Analysis (PCA) to construct composite variables for assessing technical progress, environmental degradation, and institutional efficacy. A total of twelve factors are assessed, encompassing social and economic circumstances, political stability, investment prospects, both domestic and foreign conflicts, military impact, and citizen responsibility. Institutional efficiency is evaluated by considering the amalgamation of bureaucracy quality, law and order, and corruption. In addition, the study creates an ecological footprint index (EP) by amalgamating six indicators: cropland, grazing land, buildup land, carbon, fishing grounds, and forest products. This methodology effectively overcomes the constraints observed in prior research and enhances comprehension of environmental circumstances.

$$LINPR_j = W_{j1}A_1 + W_{j2}A + W_{j3}A_3 + \cdots + W_{j12}A_{j12} \quad (1)$$

$$LECLFPR_j = X_{j1}Z_1 + X_{j2}Z_2 + X_{j3}Z_3 + X_{j4}Z_4 + X_{j5}Z_5 + X_{j6}Z_6 \quad (2)$$

Here, INPRj is the institutional performance; Wj represents weight of the parameter of the factor score; original figure of the respective indicators is represented by A. $ECLFPR$j is the ecological footprints; Xj represents weight of the parameter of the factor score; original figure of the respective indicators is represented by Z.

Table 1.
Variable Description

Variable	Description	Unit of measurement	Data Source
GDP per capita (LGDPC)	Log of GDPC	Constant 2015 US$	World Development Indicators 2021
Green Finance (GRNF)	Green finance development index is built using four indicators such as green credit, green insurance, green securities, and green investment by employing improved entropy method	Green finance index	World Development Indicators 2021
Ecological Footprint (LECFP)	Log of ECFP	Calculated through panel PCA	Global Footprint Network
Carbon Dioxide (LCO2)	Log of CO_2 per capita	CO2 metric ton per capita	World Development Indicators 2021,
Nitrous Oxide (LN2O)	Log of N_2O	Metric tons of CO_2 equivalent	World Development Indicators 2021,
Institutional Performance (LINPR)	Log of INPR	Calculated through panel PCA	ICRG
Digital governance (DGGV)	Log of DGGV	Comprehensive development index of digital government governance	World Development Indicators 2021

Source:
Author's Compilation

Cross-sectional dependence

In 2013, Chudik and Pesaran introduced the initial iteration of the Lagrange multiplier (LM) test, which has since become a widely employed method for assessing cross-sectional dependence (CSD) in panel data.

The LM test proposed by Breusch and Pagan in 1980 is presented here in a standardized format (equation 3):

$$LM_{BP} = T \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\partial}_{ij}^2 \qquad (3)$$

The sample estimate of the pair-wise correlation coefficients is denoted by $\hat{\partial}_{ij}^2$, where ij represents the sample.

Even with a large T and a small Π, LM_{BP} fails when the average pair-wise correlation approaches zero. Regardless of the values of Π and T, Sadiq et al. (2022) presented a scaled LM test. The LM test, developed by Breusch and Pagan in 1980, is an improvement over the LM_{BP} test that came before it.

$$\text{Scaled } LM\ Test = \sqrt{\left(\frac{1}{\Pi(\Pi-1)}\right)} \left[\sum_{i=0}^{\Pi-1} \sum_{j=i+1}^{\Pi} (T\partial_{ij}^2 - 1)\right] \qquad (4)$$

According to De Hoyos et al. (2006), one of the issues in LM_{BP} test is large N and small T, and to resolve the issue, he introduced the CSD test. The underlying assumption of this test is that size distortion only occurs when N(Π)>T, and thus CSD minimise it.

$$CD = \sqrt{\left(\frac{2T}{\Pi(\Pi-1)}\right)} \left[\sum_{i=0}^{\Pi-1} \sum_{j=i+1}^{\Pi} \partial_{ij}\right] \qquad (5)$$

Type equation here.Though De Hoyos (2006) has made significant and notable contribution in CSD, yet precession of CSD ha been under question and recently Bailey et al. (2021) introduced a more robust measure of CSD test capable of calculating the mean and variance of LM statistics. Thus the equation 21 can be rewritten as

$$LM_{adj} = \sqrt{\left(\frac{2T}{\Pi(\Pi-1)}\right)} \sum_{i=1}^{\Pi-1} \sum_{j=i+1}^{N} \partial_{ij} \frac{(T-k)\partial_{ij}^2 - \mu_{Tij}}{\sqrt{v_{Tij}^2}} \qquad (6)$$

Type equation here.Where μ_{Tij} and v_{Tij}^2 are the exact mean and variance of $(T-k)\,\partial_{ij}^2$ tabulated by Baltagi et al (2012).

Panel unit root test (CIPS-test)

The CIPS panel unit root test due to its ability to capture homogeneity and cross-sectional independence is one of the robust and reliable tests for unit root. The second-generation unit root test such as C CS augmented Im, Pesaran, and Shin (CIPS) and CS augmented Dickey-Fuller (CADF) tests offer more reliable and valid results than the first-generation unit root tests and can effectively tackle issues related to cross-sectional dependency and heterogeneity.

Panel Cointegration Tests

The study employed the panel co-integration test proposed and developed by Kao (1999). The test initially has been developed in two folds, one with null hypothesis stating

"no cointegration", and other stating " integration". In our case the null- hypothesis " there is no co-integration was tested employing residual-based Dickey-Fuller test (see equation 7)

$$\Delta\hat{\varrho}_{it} = \alpha_i\hat{\varrho}_{it-1} + \varrho\sum_{j=1}^{p}\delta_{ij}\Delta\hat{\varrho}_{it-j} + \epsilon_{it} \qquad (7)$$

$\hat{\varrho}_{it}$ represents the residual resulting from cointegrating regression. α_i represents the AR parameter for the panel, and ϵ_{it} signifies the error term. The current study to not only employed the cross-sectional dependence and group-mean regression techniques developed by Banerjee (1999), but to access the validity of the null hypotheses of cointegration also adopted the Phillips-Perron test. Equation 7 can be written as:

$$\Delta\hat{\varrho}_{it} = \alpha_i\hat{\varrho}_{it-1} + \sum_{j=1}^{p}\delta_{ij}\Delta\hat{\varrho}_{it-j} + \mu_i + \lambda_i t + \epsilon_{it} \qquad (8)$$

where $\hat{\varrho}_{it}$ is the residual from the cointegrating regression, α_i is the panel-specific AR parameter, $\mu_i$and λ_i are the panel-specific intercept and trend terms, and ϵ_{it} is the error term.

PMG Estimation Technique

Pool Mean Group (PMG) is employed to access and estimate the correlation between the explanatory and dependent variables. We have employed the Pooled Mean Group (PMG) estimator is a statistical method that imposes the constraint of identical long run coefficients, while allowing for variations in short run coefficients and error variances across different groups (Alola et al., 2019). The PMG method exhibits robustness when compared to other methods, especially in the cases involving modest cross-sectional dimensions. Another benefit of PMG is it address both long-run and short run, which provide robust solution for endogeneity concerns. The PMG estimator offers more reliability compared to alternative estimators in the presence of outliers and lag orders (Sucharou et al., 2019). The PMG model of current study are as follow.

$$\begin{aligned}\Delta LECFPR_{it} = \alpha_0 &+ \sum_{i=1}^{p} LECFP_{it-1} + \sum_{i=1}^{q} LINPR_{it-1} + \sum_{i=1}^{r} LDGGV_{it-1} + \sum_{i=1}^{s} LGRNF_{it-1} \\ &+ \sum_{i=1}^{t} GDPC_{it-1} + \pi_1 LECFPR_{it-1} + \pi_2 LINPR_{it-1} + \pi_3 LDGGV_{it-1} + \pi_4 LRGRNF_{it-1} \\ &+ \pi_5 GDPC_{it-1} + \mu_{it} \qquad (9)\end{aligned}$$

$$\begin{aligned}\Delta LCO2_{it} = &\sum_{i=1}^{p} LECFP_{it-1} + \sum_{i=1}^{q} LINPR_{it-1} + \sum_{i=1}^{r} LDGGV_{it-1} + \sum_{i=1}^{s} LGRNF_{it-1} + \sum_{i=1}^{t} GDPC_{it-1} \\ &+ \pi_1 LECFP_{it-1} + \pi_2 LINPR_{it-1} + \pi_3 LDGGV_{it-1} + \pi_4 LRGRNF_{it-1} + \pi_5 GDPC_{it-1} \\ &+ \varepsilon_{it} \qquad (10)\end{aligned}$$

$$\begin{aligned}\Delta LN2O_{it} = &\sum_{i=1}^{p} LECFP_{it-1} + \sum_{i=1}^{q} LINPR_{it-1} + \sum_{i=1}^{r} LDGGV_{it-1} + \sum_{i=1}^{s} LGRNF_{it-1} + \sum_{i=1}^{t} GDPC_{it-1} \\ &+ \pi_1 LECFP_{it-1} + \pi_2 LINPR_{it-1} + \pi_3 LDGGV_{it-1} + \pi_4 LRGRNF_{it-1} + \pi_5 GDPC_{it-1} \\ &+ \eta_{it} \qquad (11)\end{aligned}$$

The models employed in this study incorporate the lags of dependent variables as independent variables and apply a logarithmic transformation to each variable. The error terms in models 9, 10, and 11 are denoted as μ_it, ε_it, and η_it. Prior research has predominantly utilized univariate indicators such as corruption, freedom, government stability, and political terror. Nonetheless, the interconnectedness of different institutional elements poses a difficulty in incorporating all of them into a unified estimation. Assessing an organization's achievement based on a single metric can result in incomplete and skewed outcomes. Prior research has employed carbon dioxide, nitrous oxide, and methane as alternatives to mitigate ecological deterioration.

RESULTS AND DISCUSSIONS

Descriptive Statistics

Table 2 shows the descriptive statics of the EXPANDED BRICS countries under consideration

Table 2.
Descriptive Statistics

Variable	Mean	Median	Max.	Min.	Std. Dev.	Skewns.	Kurtosis	Obs.
	Expanded Countries							
LECFP	1.16	1.32	2.13	-2.27	0.60	-2.48	12.45	921
LCO2	1.40	1.44	2.72	0.02	0.67	0.14	2.36	921
LN2O	8.29	8.48	10.26	6.32	1.25	-0.17	1.64	921
LDGGV	0.47	0.59	1.33	-2.20	0.92	-0.81	3.15	921
LINPR	1.58	1.67	2.19	-4.41	0.71	-4.65	42.29	921
LGRNF	21.57	21.61	21.48	14.21	1.20	-0.70	3.56	921
LGCAP	8.66	8.63	9.41	7.31	0.51	-0.65	2.67	921

Source:
Author's Computation

Results of Cross Section Dependence

There is a way to evaluate the cross-section dependence in data using cross-section dependence tests, like the one Salman et al. (2019) created. Panel data analysis often makes use of tests such as the Lagrange multiplier (LM) and Pasaran CD tests to assess cross-section dependence (CSD). The correlation between the two factors is considered in these analyses. In these tests, the alternative hypothesis states that the variables are dependent on each other across time, contrary to the null hypothesis which states that this is not the case. Table 3 shows that there is cross-sectional dependence. The BRICS group now includes both high-income and middle-income countries.

Second Generation Unit Root Test

The first-generation unit root test stops working once cross-section dependence is found. This matter has been investigated using two econometric tests. Christoforidis and Katrakilidis (2021) presented the CS-augmented Dickey-Fuller (CADF) test as part of the second generation of unit root tests. In Table 4, we can see that the variables we looked at, namely I(0) and I(1), have a mixed integrated order. Most of the variables don't stay constant even when we set the initial conditions to zero. At the initial point in time (I(1)), none of the variables have changed.

Table 3.
Cross-Section Dependence in residuals

	Expanded BRICS countries					
	Model 1 LECF		**Model 2 LCO2**		**Model 3 LN2O**	
Cross-Section Dependence Tests (d.f =15)	Statistic	P-Value	Statistic	P-Value	Statistic	P-Value
Breusch-Pegan LM Test	82.35	0.00*	71.46	0.00*	0.00	0.00*
Pasaran scaled LM test	10.19	0.00*	11.50	0.00*	0.00	0.00*
Pasaran CD	4.35	0.00*	-1.46	0.00*	0.00	0.00*

Note: *, ** and *** refer to the levels of significance at 1%, 5%and 10%, respectively.

Table 4.
Second Generation Panel Unit Root Test

	EXPANDED BRICS Countries			
Variable	CIP		CADF	
	Level	1st Diff.	Level	1st Diff.
LECFP	-1.42	-3.60*	-1.69	-3.85*
LCO_2	-2.86***	-4.51*	-1.96	-4.48*
LN_2O	-4.48*	-5.08*	-1.21	-2.36**
LDGGV	-1.65	-4.12*	-2.59	-3.72*
LINPR	-1.75	-3.93*	-2.18	-3.28*
LGRNF	-3.00*	-4.68*	-3.33*	-3.84*
LGCAP	-2.25***	-3.66*	-2.73	-2.84***

Note: *, ** and *** refer to the levels of significance at 1%, 5%and 10%, respectively.

Tests of Cointegration

Methodologies proposed by Yardimcioglu et al. (2014) have been implemented in three distinct cointegration tests to examine the existence of long-term relationships among variables. Long-term cointegration of the variables is hypothesized to exist under the alternative hypothesis and not under the null hypothesis. The results of the cointegration tests are printed in Table 5. The findings indicate that variables in high-middle income countries demonstrate long-term co-integration across all three models. Additionally, high-income nations have ratified long-term integration.

Table 5.
Pedroni Cointegration test

Ho: No Coint.	**EXPANDED BRICS Countries**					
	Model 1 LECF		**Model 2 LCO2**		**Model 3 LN2O**	
	Statics.	**p-value**	**Statics.**	**p-value**	**Statics.**	**p-value**
Modified variance ratio	-2.55	0.00*	-2.16	0.02**	-2.72	0.00*
Modified Phillips-Perron	1.43	0.03***	1.43	0.05***	0.58	0.21
Phillips-Perron	-3.31	0.00*	-1.44	0.08***	-6.61	0.00*
ADF	-2.80	0.00*	-1.59	0.06***	-6.41	0.00*

Note: *, ** and *** refer to the levels of significance at 1%, 5% and 10%, respectively

Presented in Table 6 are the findings that were obtained from the cointegration tests that were carried out by Kao (1999). According to the findings, there are indications of long-term co-integration in the variables that are included in all three models for countries that have a high-medium income income level. Furthermore, empirical evidence has demonstrated that wealthy nations have long-term integration and integration.

PMG Long Run Estimates

An exhaustive analysis of the BRICS nations in its expanded form has provided researchers with a better understanding of the intricate relationship that exists between institutional and economic factors, as well as the profound impact that these factors have on ecological footprints, carbon dioxide emissions, and nitrogen oxide emissions. The most important thing to note is that the performance of institutions has a significant impact on the environmental variables that are being discussed. As little as one percent improvement in institutional performance is all that is required to bring about a significant reduction in environmental footprints and emissions of carbon dioxide and nitrogen dioxide, according to studies. This lends credence to the suggestion that robust institutions are required in order to foster more responsible environmental management, which is in line with the findings of previous research. The abundance of evidence that supports the inverse relationship brings to light the significance of establishing better institutional frameworks to protect the environment, particularly in countries with middle-income and upper-income levels of income.

Table 6.
Kao Test of Cointegration

Ho: No Cointg.	**Expanded BRICS Countries**					
	Model 1 LECF		**Model 2 LCO2**		**Model 3 LN2O**	
	Statics.	p-value	Statics.	p-value	Statics.	p-value
Modified DF	0.19	0.45	-1.82	0.04**	-0.72	0.23
DF	1.72	0.04**	-2.93	0.00*	-1.74	0.04**
ADF	1.66	0.03**	-2.23	0.02**	-1.24	0.10
Unadjusted modified DF	-0.40	0.36	-2.50	0.00*	-3.55	0.00*
Un-adjusted DF	1.47	0.08***	-3.21	0.00*	-3.26	0.00*

Note: *, ** and *** refer to the levels of significance at 1%, 5% and 10%, respectively. DF=Dicky Fuller

The study also examines the effects of digital governance and state-of-the-art scientific breakthroughs. These factors have varying impacts on environmental indicators, which is intriguing. Although they have a beneficial impact on ecological footprints and nitrogen oxide emissions, they have an adverse impact on carbon dioxide emissions. Based on current evidence, digital governance has successfully decreased CO2 emissions temporarily, but it has not had any noticeable impact on ecological footprints or N2O emissions. This juxtaposition emphasizes the intricate correlation between technological advancement and its impact on the environment. This challenge exemplifies the struggle to balance environmental conservation with technological progress. An illustration of this phenomenon is the manner in which digital governance has amplified the ecological

footprints in certain middle-income countries.All three models demonstrate a negative correlation between LDGGV and GDP per capita, CO_2 emissions, and N2O emissions. This implies that an increase in digital governance leads to a decrease in these factors. The findings of this study indicate that implementing efficient digital governance could have a substantial impact on reducing atmospheric emissions. Two methods to accomplish this goal are advocating for environmentally sustainable economic practices and enhancing the efficacy of regulations. In the third model, there is a positive correlation between LINPR (presumed to be an indicator of the institution's performance) and LN2O and LCO2, which is different from the negative correlation observed in the first two models. This outcome suggests that robust institutional performance typically results in reduced CO2 and N2O emissions. However, there may be certain circumstances or mechanisms where it unintentionally leads to increased emissions of certain types. For instance, emissions are associated with different forms of development, such as the growth of industrial facilities.

Table 7.
Estimates of PMG Regression Analysis

	EXPANDED BRICS Countries		
Variable	Model 1 (LEF) Coeff.	Model 2 (LCO_2) Coeff.	Model 3 (LN_2O) Coeff.
Long Run Results			
LDGGV	-0.51 (0.000**)	-0.69 (0.000***)	-0.74 (0.000*)
LINPR	-1.02 (0.000***)	-1.05 (0.000*)	0.19 (0.000***)
LGRNF	-0.35 (0.003**)	-0.41 (0.000*)	-0.63 (0.000*)
LGCAP	0.86 (0.000**)	1.20 (0.000**)	1.32 (0.00*)
Short Run Results			
D(LDGGV)	-0.19 (0.004**)	0.00 -0.72	-0.18 (0.003**)
D(LINPR)	-0.88 (0.000***)	-0.98 (0.007***)	-0.99 (-0.000**)
D(LGRNF)	0.104 (0.000***)	-0.103 (0.002**)	-0.102 (-0.48)
D(LGCAP)	1.49 (0.003**)	0.290 (0.74)	0.76 (-0.211)
C	1.23 (-0.54)	2.62 (0.02**)	1.17 (0.02**)
ECM	-0.51 (0.044***)	-0.62 (0.001***)	-0.78 (0.000***)

Note: * ,* and *** indicate significant of coefficient at level of significance 1% , 5% and 10% respectively. The values in parenthesis are the respective probability values.

According to the LGRNF metric, which is an indicator of green finance, there is a negative correlation across all models, which suggests that initiatives pertaining to green finance have the potential to reduce harmful emissions and GDP per capita. The significance of policies and financial instruments that promote environmental sustainability is brought into focus by this. The LGCAP variable, which has a positive correlation across all models,

suggests that an increase in economic capacity or capital could lead to an increase in GDP per capita and emissions. This relationship holds true regardless of the model. It is anticipated that this outcome will occur, however, unless proactive remediation through the implementation of environmentally friendly policies or technologies is carried out.

Initial differences between LDGGV and LINPR have negative coefficients, which indicates that these relationships will manifest in the immediate future. Short-run outcomes demonstrate how these relationships will manifest. This indicates that there is a possibility that there will be temporary reductions in emissions if there is an immediate improvement in the performance of institutions and digital governance. It can be deduced from the fact that the ECM coefficients exhibit statistically significant negative values for every variable that the long-term equilibrium relationships among these variables are eventually restored after transient disruptions.

The multifaceted nature of the environmental challenges that the expanded BRICS nations are currently facing is brought into focus by these findings. It is necessary to implement comprehensive strategies, which should include digital governance, strategic foreign investments, well-thought-out trade policies, and economic transformations that prioritize environmental sustainability. All of these factors have an impact on the environmental outcomes of these countries, which is why it is necessary to formulate policies that are both balanced and integrated.

CONCLUSION AND POLICY IMPLICATION

Green financing, institutional performance as measured by GDP per capita, emissions of carbon dioxide and nitrous oxide, and economic capacity are all illuminated by a more thorough econometric study of the BRICS countries. This study is crucial for a complete understanding of the complex issues surrounding sustainable development and environmental conservation in these developing economies. This study found that emissions, GDP per capita, and CO2 emissions are all drastically reduced by digital governance (LDGGV). This discovery is crucial. Important as it is to promote environmentally conscious business practices, this finding demonstrates the necessity for robust digital governance systems. It is evident that digital governance can decrease environmental impacts since all models showed negative coefficients. To reach this objective, it is necessary to enhance regulatory frameworks and encourage the creation of environmentally friendly technologies.

Notable here is the intricate interplay between the LINPR (institutional performance) independent variable and the dependent variables. A model's positive correlation finding in the presence of robust institutional frameworks suggests that variables like industrial expansion may unintentionally cause emissions to rise. This remains true despite the fact that it helps reduce CO2 and N2O emissions on a whole. Improving institutional performance and fully integrating environmental factors into development plans are critical due to the complexity of the outcome. Green financing, or LGRNF for short, has long-term benefits, such as a rise in GDP per capita and a dramatic drop in emissions. Its validity is demonstrated by its negative coefficients. To help the BRICS countries reach

their environmental goals, green finance initiatives are crucial, since financial policies and investments are at the heart of sustainability efforts. The study found that higher emissions and GDP per capita are associated with LGCAP. When we attempt to expand our economy while simultaneously preserving the environment, we keep running into problems like this. Taken together, these factors highlight the critical importance of using environmentally friendly methods and resources in order to achieve economic growth. In the end, the BRICS nations can incorporate the study's significant findings into their policies. The text emphasizes the significance of digital governance, improving institutional performance, prioritizing green finance, and managing economic growth prudently as ways to promote sustainable development that is environmentally conscious. These nations now have an example of how to achieve sustainability and prosperity by balancing economic growth with environmental protection.

DECLARATIONS

Acknowledgement: We appreciate the generous support from all the supervisors and their different affiliations.
Funding: No funding body in the public, private, or nonprofit sectors provided a particular grant for this research.
Availability of data and material: In the approach, the data sources for the variables are stated.
Authors' contributions: Each author participated equally to the creation of this work.
Conflicts of Interests: The authors declare no conflict of interest.
Consent to Participate: Yes
Consent for publication and Ethical approval: Because this study does not include human or animal data, ethical approval is not required for publication. All authors have given their consent.

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