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Navigating the Path to Sustainable Development in BRICS Countries

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ABSTRACT

This study is a comprehensive analysis of the economic, environmental and social efficiencies of the BRICS countries (Brazil, Russia, India, China and South Africa) from 2010 to 2023, using the data envelopment analysis (DEA) method. In an innovative extension, the study estimates a second-stage regression to explore the impact of institutional support, specifically financial disbursements from the New Development Bank (NDB), on national sustainable development performance. Key findings reveal that Russia maintains the highest economic efficiency, averaging 94%, despite geopolitical tensions and economic pressures. Brazil, while initially leading in earlier years, shows a fall to 83%, reflecting challenges in maintaining high efficiency. India and China exhibit moderate economic efficiency, by structural and environmental challenges. South Africa, despite low inputs and outputs, achieves notable efficiency, particularly in environmental and social dimensions, with scores of 98% and 95.57% respectively. The findings suggest that bloc-level cooperation, through mechanisms like the NDB, can contribute positively to national efficiency outcomes. This paper contributes to the literature by integrating institutional development finance into a DEA framework and offering a comparative perspective on BRICS countries' sustainable growth trajectories within the Global South.

1 | Introduction

Since their formal recognition as a cohesive group in 2009, the BRICS countries—Brazil, Russia, India, China and South Africa—have evolved from initially loose cooperation (Lowe 2016) to regular summits aimed at formulating joint economic policies and strategies. This transition has led to the establishment of institutions like the New Development Bank (NDB), focusing on sustainable development and financial co-operation. While the main focus of this study is on the internal use of resources and policy efficiency within BRICS nations, it is important to acknowledge the role of multilateral financing initiatives such as the NDB. Between 2015 and 2023, the NDB approved over USD 31.9 billion in development projects across BRICS countries, with a strong emphasis on infrastructure, clean energy and social sectors (NDB 2023). These initiatives are likely to have exerted an indirect but increasingly significant influence on key data envelopment analysis (DEA) input variables, particularly gross fixed capital formation (GFCF) and research and development (R&D) expenditure. To reflect this influence, the present study integrates the NDB's role by adjusting input variables in line with disbursement trends, particularly in the post-2015 period. This approach allows us to account for the external support provided by the NDB while maintaining the internal focus of the DEA model. The analysis thus recognises the NDB's impact as a contextual factor in the efficiency performance of each country. Future studies may further enhance this approach by incorporating NDB funding as a nondiscretionary input or environmental variable within a two-stage DEA or regression-adjusted framework.

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The BRICS countries were chosen for this study not just for their economic importance. They are key players in global economic development and essential for future progress (Tian et al. 2020; O'Neill 2021). These nations are strategically important as they embody diverse development models and economic strategies, presenting unique challenges and opportunities that make them ideal subjects for a comparative analysis of development trajectories (Downie and Williams 2018). Brazil and Russia are primarily exporters of raw materials, leveraging their rich mineral reserves. In contrast, China has emerged as a major manufacturer due to its vast labour force, while India has become a significant service provider (Streltsov et al. 2021; Chatterjee and Naka 2022). South Africa stands out as the most industrialised nation in Africa, with substantial mineral wealth and a reputation as a stable investment destination (Lowe 2016). While they follow diverse development paths and face distinct structural challenges, all five nations share a common interest (Basu et al. 2013) in promoting sustainable growth and South–South cooperation, such as significant trade in intermediates among themselves (De Mello-Sampayo 2017a; De Mello-Sampayo 2017b). The BRICS bloc has also established institutional mechanisms, such as the NDB, that reflect a collective commitment to infrastructure and sustainability financing. These shared features provide a compelling context for comparative efficiency analysis, especially when assessing how supranational cooperation influences national development performance. Focusing on BRICS allows us to evaluate both the heterogeneity and the potential convergence of sustainability strategies within a high-impact geopolitical group.

Following Santana et al. (2014) and Gebert and de Mello-Sampayo (2025), this study evaluates the sustainable development performance of BRICS countries using the DEA method. This method enables the ranking of BRICS countries based on their economic, environmental and social efficiency. Specifically, we analyse how effectively these countries have utilised their productive resources and technological innovations to achieve sustainable development over a 13-year period (2010–2023). In addition to the traditional DEA approach, this study employs a window analysis to capture efficiency trends over time and incorporates a second-stage regression to examine the potential influence of institutional financial support, namely disbursements from the NDB, on national efficiency outcomes.

This timeframe encompasses a critical period of substantial economic evolution and transformation within these nations, marked by significant global events that have influenced their development paths. The year 2010 is a strategic starting point as it follows the 2008 global financial crisis—a period during which the BRICS countries implemented significant economic reforms and stimulus measures to stabilise and rejuvenate their economies. Notably, China's fiscal stimulus in 2008, which amounted to 12% of its GDP, focused heavily on construction and infrastructure development (Naughton 2008; Zhang et al. 2013). Conversely, 2023 serves as the cut-off period, providing the most recent comprehensive data and encompassing the economic disruptions and policy responses related to the COVID-19 pandemic, thereby offering insights into how the BRICS countries have navigated unprecedented global challenges. During this timeframe, several major events such as the sanctions Russia faced following its 2014 annexation of Crimea and subsequent invasion of Ukraine (Bělín and Hanousek 2021) have also played a substantial role in shaping the economic landscapes and policy responses of these countries. This study considers these and other pivotal events to provide a comprehensive analysis of the BRICS' development trajectories.

Extending the analysis captures the evolving sustainability efforts within these countries, providing updated insights into their progress and challenges in achieving sustainable development. Continuous monitoring is crucial for adapting to changes and offering policymakers actionable insights for effective strategies. By addressing the impacts of the pandemic, geopolitical conflicts and economic pressures, this research ensures that development policies remain relevant and responsive, fostering sustainable development in a rapidly changing global environment. This paper contributes to the literature by offering a comparative analysis of the BRICS countries' economic strategies and outcomes, highlighting their unique development models and providing insights into diverse pathways to development within the Global South.

We analyse the individual economic policies and development outcomes of the BRICS countries within the broader context of economic growth theories and sustainable development. Economic growth theories have evolved from focusing on capital accumulation, typical of classic and neoclassic frameworks, to emphasising human capital in more recent theories like endogenous growth theory (Choudhry et al. 2020). Doré and Teixeira (2023) organised these factors into seven categories: human capital, labour and demographic conditions, technology and innovation, macroeconomic conditions, international trade and FDI, natural resources and institutional conditions. The influence of these factors, however, varies greatly across different countries (Chirwa and Odhiambo 2016). In developed nations, physical capital, fiscal policy and human capital are critical, while developing countries often prioritise external elements such as FDI and foreign aid. The interplay of these factors is further complicated by issues like income inequality, labour exploitation and environmental degradation, highlighting the need for quality growth that truly enhances well-being (Ranis et al. 2000; López et al. 2008). This recognition has led to the creation of new indicators including the human development index, the Gini coefficient and life expectancy at birth (Chen et al. 2021; Hasell 2023).

The concept of sustainable development emerged as a response to these challenges, seeking to balance economic growth with environmental conservation (Almeida et al. 2017; Brundtland 1987). Its origins can be traced back to classic economists such as Malthus, Smith, Ricardo and Mill, who raised concerns about the sustainability of economic growth and its long-term impacts (Purvis et al. 2019). The concept gained attention following the 1972 Stockholm Conference, which led to the establishment of the United Nations Environmental Program (UNEP). This conference underscored the conflict between environmental protection and developmental needs of various countries (Chasek 1994; Prizzia 2017). Sustainable development was formally defined in the Brundtland Report

(1987) as meeting present needs without compromising the ability of future generations to meet their own needs. The term ‘sustainability’ has since evolved to include social, economic and environmental dimensions. This three-pillar model, although not explicitly outlined in foundational documents like the Brundtland Report or Agenda 21, has become a widely accepted framework for understanding sustainability (Moldan et al. 2012; Purvis et al. 2019). Brown et al. (1987) and Pope et al. (2004) further examined these dimensions, emphasising the integration of social needs, environmental protection and economic growth as essential for implementing sustainable development.

This paper next discusses BRICS countries' development. The methodology section explains the research design and analysis techniques employed. The findings and analysis are then presented, and the paper concludes with a summary of the main points and suggests areas for future research.

2 | Related Literature

The economic, environmental and social development of the BRICS countries has been a subject of considerable research and analysis. Hluszko et al. (2024) provide a systematic literature review on how BRICS countries approach sustainable concerns, identifying primary strategies and policies employed. Table 1 provides a comprehensive overview of how different studies approach the complex interplay between economic, environmental and social sustainability in the BRICS countries. Santana et al. (2014) assess the socio-economic performance of BRICS, noting Brazil's efficiency in resource use and the need for China and India to reduce pollution. Similarly, Gebert and de Mello-Sampayo (2025) reveal Russia's and South Africa's leadership in sustainability aspects, while identifying pollution and quality of life issues in China and India. Studies by Ozturk (2015) and Menegaki (2016) explore the intricate relationships between energy consumption, economic growth and CO_2 emissions, emphasising the role of renewable energy in promoting economic and environmental health. Zaman et al. (2016) add support to this by demonstrating the positive impact of renewable energy on economic growth and highlighting the benefits of financial development and trade openness on sustainability. Erdogan (2021) finds that while economic growth can lead to environmental degradation, renewable energy mitigates these negative impacts. Ucan et al. (2023) discuss how technological development and globalisation help reduce the ecological footprint. Studies by Ofori et al. (2023) and Pata et al. (2024) corroborate these findings by illustrating the positive relationship between renewable energy investments and economic growth, and the role of sustainability policies in improving social outcomes. These studies underscore the need to integrate sustainable practices into economic policies to achieve growth and sustainability across BRICS countries.

These countries have experienced substantial economic growth, leading to the lifting of millions of people out of poverty and improvements in health indicators (Cao 2018). The existence of a substantial middle class in each BRICS country has been identified as a key driver of economic development in these nations (Jakovljević 2014). As the middle class grows, there will be an increased demand for energy and resources, challenging the sustainability of resource allocation (Sahu 2016). However, this economic development has also been accompanied by challenges such as increased carbon emissions due to rapid urbanisation and industrialisation (Wen 2024). The environmental impact of this growth is evident in the form of serious environmental pollution (Liu 2022).

The rapid economic expansion has raised concerns about the exploitation of natural resources and environmental impact (Gomes and Silva 2017). BRICS countries face challenges related to climate change, with varying approaches to sustainable development and energy use (Brütsch and Papa 2013; Cavalcanti 2018). Each BRICS country provides detailed reports on its commitments to the UN's Sustainable Development Goals and Millennium Development Goals. However, Basile and Cecchi (2019) noted inconsistencies in their engagement with these goals and the Paris Agreement, with a continued dependence on traditional energy sources in some countries. These studies highlight the complex interplay between economic growth and sustainable development in BRICS countries. The integration of sustainable practices into economic policies is essential to achieve growth and sustainability across these diverse nations (BRICS 2015).

Despite the economic growth, there is a need for joint action among the BRICS nations to address social and economic determinants that impact health and sustainable development (Buss et al. 2014). The impact of trade balance, economic growth, energy use and urbanisation on environmental sustainability in BRICS countries is a subject of study (Rahman and Halim 2022). As the BRICS countries continue to develop, there is a growing demand for energy and resources, which poses challenges for sustainability (Sahu 2016). Efforts are being made to ensure the sustainability of labour markets in these countries and promote inclusive policies (Beletskaya 2022). Efforts are being made to mobilise resources for sustainable development projects and enhance cooperation in financial, educational and industrial sectors (Zavyalova et al. 2020). Additionally, the BRICS countries are exploring cooperation in areas such as internet governance, financial technologies and higher education to support sustainable development (Albekov and Lakhno 2018; Zvereva et al. 2020; Ignatov 2022; Zavyalova et al. 2020). The economic integration of BRICS countries is seen as a driver of regional and global economic growth, transforming their economic potential into political influence (Parfinenko 2020). Additionally, the BRICS countries are actively engaging in international cooperation, including with African nations, using ‘soft power’ to foster cultural and scientific ties (Deych 2015).

The BRICS countries have made strong steps in economic and social development, but challenges such as environmental pollution and sustainability remain. Collaborative efforts within the BRICS group and with other nations are essential to address these challenges and ensure continued progress toward sustainable development. At the 16th BRICS Summit held in 2024, the NDB reaffirmed its commitment to financing infrastructure and sustainable development projects across member states, underscoring the importance of coordinated

TABLE 1 | Sustainable development in BRICS countries.

Study	Period/methodology	Findings
Sustainable development in the BRICS countries: an efficiency analysis by data envelopment, (Santana et al. 2014)	2001–2007DEA (data envelopment analysis)	Assesses the socio-economic performance of BRICS countries. Brazil excels in resource use, while China and India need to focus on reducing pollution.
Sustainability in the food-energy-water nexus: evidence from BRICS (Brazil, the Russian Federation, India, China, and South Africa) countries (Ozturk 2015)	1980–2013 PCA (principal component analysis) to construct a food security index; GMM (generalised method of moments) system.	Energy consumption, economic growth and CO_2 emissions are interrelated. Renewable energy reduces CO_2 emissions.
Alternative energy and growth in BRIC countries, Energy Sources (Menegaki 2016)	1992–2008 Fixed effects model with time effects, dynamic effects model	Alternative energy and full energy consumption are causally related to GDP. CO_2 emissions and labour negatively affect GDP growth.
Dynamic linkages among energy consumption, environment, health, and wealth in BRICS countries: Green growth key to sustainable development (Zaman et al. 2016)	1975–2013 FMOLS (panel fully modified OLS); DOLS (dynamic OLS)	Renewable energy consumption positively impacts economic growth. Financial development and trade openness enhance sustainability.
Dynamic nexus between technological innovation and building sector carbon emissions in the BRICS countries (Erdogan 2021)	1992–2018 DCCE (dynamic common correlated effects) and PMG (pooled mean group/panel ARDL)	Economic growth is positively related to environmental degradation. Renewable energy mitigates some negative impacts.
Determinants of ecological footprint in BRICS countries: a panel data analysis. (Ucan et al. 2023)	1992–2015 CCEMG (common correlated effects mean group)	Energy consumption, technological development and globalisation reduce ecological footprints. Urbanisation impacts vary by country.
Achieving carbon neutrality in post COP26 in BRICS, MINT, and G7 economies: the role of financial development and governance indicators (Ofori et al. 2023)	1996–2020 Pool OLS-fixed effects model; Prais–Winsten comparative analysis	Positive relationship between renewable energy consumption and economic growth in BRICS. Energy consumption leads to economic growth.
Ecological effects of distinct patents on reducing waste-related greenhouse gas emissions in BRICS countries: evidence from novel quantile methods, (Pata et al. 2024)	1997–2019 Quantile-on-quantile regression (QQ), Granger causality-in-quantiles (GQ) and quantile regression (QR)	Renewable energy investments lead to economic growth. Policies promoting sustainability positively impact economic performance.
Efficiency of BRICS countries in sustainable development: a comparative data envelopment analysis. International Journal of Development Issues. (Gebert and de Mello-Sampayo 2025)	2010–2018 DEA (data envelopment analysis)	Russia and South Africa lead in sustainability aspects. Brazil is efficient in resource use. China and India face pollution and quality of life issues.
Environmental Sustainability in BRICS Economies (Asif et al. 2024)	2004–2023 Panel data analysis	Technological innovation, financial development and renewable energy consumption positively influence sustainability.
Evolving efficiency of the BRICS markets (Kulikova et al. 2024)	Time-varying moving window tests; Kalman filter	Examines changes in market efficiency over time in BRICS countries.

Source: Authors.

investment strategies in achieving long-term development goals (NDB 2024).

3 | Methodology

The DEA model is employed to measure and compare the efficiency of BRICS countries during the period from 2010 to 2023 using data from the World Data Bank. We conducted three separate DEA analyses, each focusing on one of the sustainable development pillars: economic, social and environmental sustainability. DEA is a nonparametric linear programming approach used to evaluate the efficiency of decision-making units (DMUs) that utilise multiple inputs to produce multiple outputs (Charnes et al. 1978). This study employed the BCC model (Banker et al. 1984), which allows for variable returns to scale (VRS), meaning that outputs can change in a nonproportional manner relative to inputs. The output-oriented DEA-BCC model, which focuses on maximising output efficiency given a set of inputs, was used to assess economic, social and environmental efficiencies. The specific equations used in the model are reported in Table 1.

To analyse efficiency trends over time, the 'window analysis' technique (Cooper et al. 2007) was applied. This method treats each unit per year as a distinct DMU and calculates a moving average by adding new units and removing old ones. The number of windows and their amplitudes were determined based on the total number of years analysed, as shown in Table 2. In this study, seven windows were created, each covering an 8-year period.

To refine the efficiency scores, the inverted frontier method was used (Angulo Meza et al. 2003). This involves swapping the roles of inputs and outputs in the DEA model, then averaging the classic and inverted efficiency scores to form a composite index, normalised against the highest score (Leta et al. 2005).

For the output variables in this study, gross domestic product (GDP) was chosen to represent economic growth, consistent with its use in previous research (Apergis and Payne 2011; Sanz-Díaz et al. 2017). Life expectancy was selected to capture the social dimension, aligning with its role as a general health indicator in studies by Luy et al. (2020), Mariano and Rebelatto (2014) and Magombeyi and Odhiambo (2018). CO_2 emissions[1] were employed as a proxy for environmental sustainability, following its standard use as an environmental impact metric (Maryam et al. 2017; Shikwambana et al. 2021; Lee et al. 2021).

For the input variables, GFCF was used to represent the capital variable due to its well-documented correlation with economic growth (Meyer and Sanusi 2019; Topcu et al. 2020). The impact of infrastructure investment, including transportation, energy and telecommunications, varies across countries, with mixed results regarding its significance in Brazil and South Africa compared with Russia, India and China (Apurv and Uzma 2020). Calderón et al. (2015) and Kodongo and Ojah (2016) identified a strong link between infrastructure investment and economic growth. Meidayati (2017) highlighted the impact of telecommunications infrastructure and market size on developing countries' economies.

The unemployed population was chosen as a proxy for human capital. Fisher (2022) found a strong positive relationship between labour force participation and GDP per capita growth rate in BRICS from 2009 to 2019. Hartman and Kwon (2005) found that human capital significantly reduces environmental pollution in China. Nakabashi and Figueiredo (2005) further argued that human capital indirectly bolsters income growth per worker through the acceleration of technological diffusion, intensified by imports and FDI. Hu (2021) echoed these findings, emphasising the role of human capital in enhancing the benefits of imported technology and innovation.

R&D expenditure was included to gauge the impact of technological innovation on sustainable development (Bayarçelik and Taşel 2012; Costantini et al. 2023). Technological advancements, R&D expenditure and knowledge spillovers contribute significantly to BRICS' productivity and competitiveness (Franco and Oliveira 2017; Hu 2021). Innovation investments bolster economic growth (Gyedu et al. 2021). Ndlovu and Inglesi-Lotz (2020) explored variations in the impact of R&D expenditure on economic growth across BRICS countries.

Foreign direct investment (FDI)[2] inflows were used, acknowledging their pivotal role in fostering innovation and sustainable development in developing countries (Sunde 2016; Sarkodie and Strezov 2019; Chai et al. 2021; Lee et al. 2021; Bezerra and

TABLE 2 | DEA-BCC model and window analysis equations.

Component	Equation
Objective	$Min \sum_{j=1}^{n} v_j \cdot x_{j0} - s$, for each window
Constraints	$\sum_{i=1}^{m} u_i \cdot y_{i0} = 1$ for each window
	$\sum_{i=1}^{m} u_i \cdot y_{ik} - \sum_{j=1}^{n} v_j \cdot x_{jk} + s \leq 0,\ for\ k = 1, 2, \ \ldots, h, \forall k$ for each window
Number of windows	$w = l - p + 1$
Window amplitude	$p = \frac{l+1}{2}$

Note: n and m are the number of inputs and outputs analysed, respectively; h is the number of decision-making units (DMUs) analysed; s is the scale factor; u_i and v_j are the weights of inputs and outputs; x_{j0} and y_{i0} are input and output amounts for the DMU being assessed; and x_{jk} and y_{ik} are the inputs and outputs for DMU k, w represents the number of windows, p represents the window amplitude and l represents the number of years.
Source: Authors.

Silva 2021). The role of FDI is debated, with some studies suggesting that it is beneficial, especially when coupled with technology transfer and capital accumulation (Khalid and Marasco 2019; Choudhry et al. 2020; Saini and Singhania 2018). Further, Khan and Nawaz (2019) observed a positive correlation between trade openness, FDI and income distribution. Long-term benefits of FDI in BRICS, aligned with technical cooperation, were noted by Prabhakar et al. (2015) and Agrawal (2015). Udi et al. (2020) identified FDI as a crucial element for South Africa's economic growth, noting that in 2017, BRICS attracted 19% of global FDI inflows (UNCTAD 2018).

A stepwise method was used to validate the variables chosen for DEA applications. This method involves starting with the most statistically significant variable and then adding or removing variables sequentially based on specific criteria. For the economic efficiency application, the inputs included GFCF, R&D, FDI and the unemployed population, with GDP as the output. In the environmental efficiency application, the same inputs (GFCF, R&D, FDI and the unemployed population) were used, but the output was CO_2 emissions. For the social efficiency application, the inputs were GFCF, R&D and FDI, with life expectancy as the output. The first and second applications thus assessed economic and environmental efficiencies, respectively, using GDP and CO_2 emissions as their outputs, while the third application focused on social efficiency with life expectancy as the output.

To account for the potential influence of multilateral financial support on country-level efficiency, we conducted a second-stage regression analysis using the efficiency scores obtained from the DEA-BCC model as the dependent variable. Specifically, we assessed whether support from the NDB significantly affected sustainable development efficiency in BRICS countries during the period 2015–2023.

Given the bounded nature of DEA scores (between 0 and 1), a Tobit regression model was employed, which is suitable for censored dependent variables. The general form of the model is:

$$\theta_{it} = \alpha + \beta_1 NDB_{it} + \varepsilon_{it}$$

where θ_{it} denotes the DEA efficiency score for country i in year t; NDB_{it} is the natural logarithm of total NDB disbursement (in USD).[3] This analysis allows us to identify whether the external support from BRICS institutions has a statistically significant impact on the efficiency with which countries transform inputs into sustainable development outputs. As a robustness check, we also considered the Simar and Wilson (2007) double-bootstrap procedure, which accounts for bias in DEA scores and allows for valid inference under serial correlation and heteroskedasticity.

4 | Results

Table 3 reports the efficiency scores from DEA for Brazil, Russia, India, China and South Africa over seven different time windows from 2010 to 2023.

4.1 | Economic Efficiency

In the economic dimension, Russia demonstrates consistently high efficiency scores, with an average of 94.20%. Brazil,

TABLE 3 | Economic, social and environmental applications (2010–2023).

Country	Metric	2010/17 (%)	2011/18 (%)	2012/19 (%)	2013/20 (%)	2014/21 (%)	2015/22 (%)	2016/23 (%)	Mean total	Rank
Brazil	Economic	86.27	83.47	83.63	84.04	81.05	80.48	80.63	82.80	2
	Social	88.60	88.71	89.09	89.71	89.63	89.29	88.97	89.14	3
	Environmental	92.59	91.80	91.31	90.68	89.93	87.16	86.55	90.00	3
Russia	Economic	94.60	93.75	94.35	94.42	93.35	94.16	94.79	94.20	1
	Social	92.72	93.91	94.57	95.17	95.30	95.62	95.79	94.73	2
	Environmental	95.72	96.29	97.07	97.40	98.04	95.92	95.99	96.63	2
India	Economic	65.29	64.95	67.66	68.73	68.76	71.54	74.20	68.73	4
	Social	88.47	88.54	88.61	87.91	86.95	86.03	85.24	87.39	4
	Environmental	49.32	48.86	49.46	49.08	49.87	50.37	51.70	49.81	4
China	Economic	72.16	70.21	70.21	70.21	68.51	68.47	68.27	69.72	3
	Social	56.32	57.18	57.95	57.53	57.29	56.96	55.84	57.01	5
	Environmental	21.18	20.86	20.78	19.85	19.29	17.89	16.59	19.49	5
South Africa	Economic	70.72	68.69	68.69	68.80	66.86	66.83	66.56	68.16	5
	Social	90.85	96.88	97.70	98.32	95.95	95.16	94.15	95.57	1
	Environmental	99.29	99.09	99.03	99.11	99.04	96.01	95.04	98.09	1

Source: Authors.

while initially showing robust economic performance, shows a gradual decline over time, averaging 82.80%. India, although showing steady improvement in earlier years, faces challenges post-2020, likely due to the global impacts of the COVID-19 pandemic, resulting in an average score of 68.73%. China maintains relative consistency but without significant improvement, averaging 69.72%. South Africa shows a decreasing trend, averaging 68.16%, reflecting economic vulnerabilities exacerbated by global and local disruptions.

4.2 | Social Efficiency

The social dimension reveals notable trends, with South Africa achieving the highest average efficiency score of 95.57%. This indicates strong progress in social development and welfare policies. Russia follows closely with an average score of 94.73%, showcasing its efforts in social development. Brazil's social efficiency is also high, averaging 89.14%, indicating stability. India's social efficiency, while high, shows a slight drop, averaging 87.39%. China's performance in this dimension remains the lowest among the countries, with an average of 57.01%, highlighting the need for improved social policies.

4.3 | Environmental Efficiency

Environmental efficiency scores showcase a different set of challenges and achievements. South Africa leads with an impressive average score of 98.09%, underscoring its commitment to environmental sustainability. Russia also performs strongly in this dimension, with an average score of 96.63%. Brazil's environmental efficiency, although high initially, falls over time, resulting in an average score of 90.00%. India and China show lower averages of 49.81% and 19.49%, respectively, indicating sizable room for improvement in their environmental policies and practices.

4.4 | Temporal Trends—Window Analysis

Table 4 shows a comparative analysis of the efficiency scores and rankings of BRICS nations across three distinct periods: 2001–2007, 2010–2018 and 2010–2023. It shows shifts in the efficiency scores and rankings of BRICS nations across economic, social and environmental dimensions from previous periods (2001–2007 and 2010–2018) to the current period (2010–2023). Russia emerges as a consistent leader in economic efficiency, maintaining its top position from the previous period, reflecting robust economic policies. South Africa shows remarkable improvement in social efficiency, securing the highest rank, which aligns with its previous leading position while highlighting continued progress in social development. Brazil's economic and social efficiency exhibit a recovery from the earlier decline. Conversely, China continues to struggle with social and environmental efficiency, retaining the lowest ranks, which underscores ongoing challenges despite some slight improvements. India's performance shows moderate improvements in economic efficiency but remains relatively stable in social and environmental dimensions, indicating stubborn areas that need policy attention. Overall, this study underscores the dynamic nature of sustainability performance among BRICS nations, highlighting both progress and persistent challenges when compared with earlier studies.

TABLE 4 | Efficiency scores and rankings of BRICS nations across different applications and time periods.

Country	Application	Efficiency score (2001–2007)a (%)	Rank (2001–2007)a	Efficiency score (2010–2018)b (%)	Rank (2010–2018)b	Efficiency score (2010–2023)c (%)	Rank (2010–2023)c
Brazil	Economic	98	1st	77	2nd	83	2nd
	Social	99	1st	90	3rd	89	3rd
	Environmental	90	2nd	93	3rd	90	3rd
Russia	Economic	51	4th	92	1st	94	1st
	Social	89	2nd	94	2nd	95	2nd
	Environmental	78	4th	97	2nd	97	2nd
India	Economic	49	5th	70	5th	69	4th
	Social	49	5th	88	4th	87	4th
	Environmental	81	3rd	48	4th	50	4th
China	Economic	65	3rd	71	4th	70	3rd
	Social	56	4th	53	5th	57	5th
	Environmental	21	5th	15	5th	20	5th
South Africa	Economic	66	2nd	72	3rd	68	5th
	Social	76	3rd	97	1st	96	1st
	Environmental	99	1st	99	1st	98	1st

Sources: (a) Santana et al. (2014) results; (b) Gebert and de Mello-Sampayo (2025); (c) authors.

TABLE 5 | The Tobit regression.

Variable	Coefficient	Std. error	*t*-statistic	*p*
Intercept	0.397	0.140	2.836	0.011
NDB_{it}	0.045	0.023	1.947	0.067

Source: Authors.

4.5 | Second-Stage Analysis—Tobit Regression

The second-stage Tobit regression analysis presented in Table 5 shows a positive relationship between NDB financial support and DEA efficiency scores in the post-2015 period. This suggests that NDB disbursements have contributed to improvements in the countries' ability to convert resources into sustainable development outcomes. Specifically, a 1% increase in disbursement volume is associated with a 4.5% increase in the efficiency score, all else being equal.

These results are consistent with descriptive trends observed in the first-stage DEA, where India and Brazil, both major recipients of NDB financing, showed steady improvements in economic and social efficiency after 2015. Russia and China also benefited, albeit to a lesser degree. The results support integrating institutional variables in DEA studies and highlight the complementary role of supranational development banks in national policy implementation. As a robustness check, the double-bootstrap bias-corrected results preserved the direction of the effect.

5 | Discussion

Economically, Brazil's ability to convert median inputs into high outputs places it second in economic efficiency among BRICS nations from 2010 to 2023, with an average efficiency score of 83%. This score represents a significant decline from the first-place 98% efficiency score reported for the 2001–2007 period by Santana et al. (2014). The drop indicates challenges in maintaining high efficiency over time, despite Brazil's initial success. Comparatively, Gebert and de Mello-Sampayo (2025) reported a further decline to 77% for the 2010–2018 period, suggesting some recovery in the 2010–2023 period, but still highlighting the fluctuations in Brazil's economic efficiency. The paradox of high efficiency scores alongside mid-range rankings can be attributed to median input levels and the country's substantial FDI inflows, which are the second highest among BRICS nations (World Bank 2023). This suggests a potential for Brazil to improve its output maximisation. Data from the Brazilian Institute of Geography and Statistics (IBGE) indicate uneven GDP growth, influenced by fiscal policies aimed at boosting private consumption and demand. These policies, while initially successful, have contributed to economic downturns post-2013 (Costa et al. 2017). Additionally, the COVID-19 pandemic severely impacted Brazil's economy (Carvalho et al. 2023), disrupting supply chains, increasing unemployment and straining public health systems. The ongoing war in Ukraine has also contributed to economic instability by causing fluctuations in global commodity prices, which are critical to Brazil's export-driven economy.

Environmentally, Brazil ranks third with an average efficiency score of 90%, largely due to its robust renewable energy sector, particularly hydropower (IRENA 2022). However, this achievement is counterbalanced by high greenhouse gas (GHG) emissions resulting from deforestation (Timperley 2018; Weisse et al. 2023). The correlation between rising FDI and decreasing CO_2 emissions (Khatoon and Bala 2022), amid increasing deforestation, highlights the need for focused environmental policies. Compared with the 90% environmental efficiency score from 2001 to 2007 and the 93% score from 2010 to 2018 (Gebert and de Mello-Sampayo 2025), the consistent efficiency underscores Brazil's renewable energy strengths but also its environmental policy challenges (Udemba and Tosun 2022). This consistency is overshadowed by the more substantial environmental advancements made by other BRICS nations, particularly Russia and South Africa (Weisse et al. 2023; IRENA 2022).

In the social dimension, Brazil's life expectancy of around 75 years and significant reductions in inequality during the Worker's Party (PT) governance (Oliveira 2023) stand in contrast to its third-place social efficiency ranking. Initiatives such as *Bolsa Familia* have greatly improved living conditions (Campoli et al. 2019), yet political changes and a diminished focus on these programs (Costa 2019) have stalled further progress. Brazil's social efficiency score fell from 99% in 2001–2007 (Santana et al. 2014) to 90% in 2010–2018 (Gebert and de Mello-Sampayo 2025) and slightly further to 89% in 2010–2023, highlighting the impact of the COVID-19 pandemic and the war in Ukraine, which have exacerbated social and economic vulnerabilities. This underscores the need for sustained social policies to maintain and improve social development outcomes.

Despite Russia's heavy reliance on oil exports, which account for 20% of its GDP (Orazalin and Mahmood 2018; Dabrowski 2023), the challenges posed by the COVID-19 pandemic and the geopolitical implications of the war in Ukraine, Russia's efficient use of inputs (particularly in human capital and infrastructure development (Serbian et al. 2023)) has maintained its top economic efficiency ranking with an average score of 94% from 2010 to 2023. This efficiency is significantly higher than the 51% efficiency score reported from 2001 to 2007 by Santana et al. (2014) and the 92% score from 2010 to 2018 as noted by Gebert and de Mello-Sampayo (2025).

Environmentally, Russia stands second with an efficiency rate of 97%, successfully managing low CO_2 outputs from median inputs. However, as the world's fourth-largest GHG emitter (Zagoruichyk 2022), optimising R&D and FDI toward reducing emissions remains crucial. This environmental efficiency has seen a marked improvement from the 78% efficiency reported in the 2001–2007 period by Santana et al. (2014), consistent with the findings by Gebert and de Mello-Sampayo (2025), who also noted a 97% efficiency from 2010 to 2018. Socially, Russia has made significant advancements in poverty reduction, reflected in its 95% efficiency rating, despite a lower life expectancy of 72.7 years. This underscores the impact of government initiatives in social development (Rudenko and Satre 2018). The social efficiency improvements, from 89% in the 2001–2007 period to 94% in the 2010–2018 period (Gebert and de Mello-Sampayo 2025), highlight Russia's ongoing efforts to enhance social welfare amid economic and geopolitical challenges.

India had an economic efficiency score of 49% from 2001 to 2007, ranking fifth among BRICS countries. Despite post-1991 economic reforms that fuelled growth and shifted the economic structure toward services over industry (The World Bank 2018a; Anand 2014), India's economic efficiency remained low. Gebert and de Mello-Sampayo (2025) report a slight improvement to 70% in the 2010–2018 period, though still ranking fifth. This trend continues into the 2010–2023 period, with a score of 69% and a fourth-place ranking. The premature deindustrialisation might explain India's low economic efficiency, as the benefits of industrialisation remain largely unexploited. Additionally, the COVID-19 pandemic greatly impacted India's economic efficiency, with the economic disruptions resulting in a modest average score of 69% during 2010–2023. The ongoing war in Ukraine has further exacerbated economic instability and fluctuations in global energy prices and supply chains, which indirectly affect India's economic performance (IMF 2023).

Environmentally, India ranks fourth with a 50% efficiency score for the 2010–2023 period, reflecting increased CO_2 emissions alongside economic growth (Zameer et al. 2020; Timperley 2019). From 2001 to 2007, India had an environmental efficiency score of 81%, ranking third according to Santana et al. (2014). This score dropped dramatically to 48% in the 2010–2018 period, as reported by Gebert and de Mello-Sampayo (2025). The primary emission sources, including energy and agriculture, suggest inefficiencies in input utilisation and highlight the need for more effective environmental policies. Socially, India's rapid economic growth has not inclusively benefitted its population, as evidenced by its fourth-place social efficiency ranking and a life expectancy of around 69 years. India's social efficiency score improved from 49% in 2001–2007 to 88% in 2010–2018, then fell slightly to 87% in the 2010–2023 period. Initiatives aimed at reducing poverty and promoting non-farm employment (Pattayat et al. 2022) indicate potential areas for improvement. However, the pandemic and geopolitical conflicts, particularly the war in Ukraine, have strained social resources and exposed vulnerabilities in healthcare and social support systems, underscoring the need for resilient and inclusive social policies (WHO 2022; UNDP 2023).

As the world's second-largest economy, its fourth-place economic efficiency ranking may stem from its transition to a service-oriented economy and rising unemployment influenced by technological advancements (The World Bank 2018b; Du and Wei 2022). The impacts of the COVID-19 pandemic and stricter regulatory measures also contributed to China's economic efficiency, which averaged 70% during 2010–2023. This reflects challenges in effectively leveraging its economic inputs. Compared with the period from 2001 to 2007, in which China had a third-place ranking with a 65% efficiency score (Santana et al. 2014), the slight improvement in the efficiency score but a fall in rank suggests that other BRICS nations have been more effective in their economic strategies during the latter periods. Additionally, geopolitical tensions and economic disruptions, such as trade wars and the impacts of the Russia-Ukraine conflict, have further influenced China's economic performance (Gebert and de Mello-Sampayo 2025).

In environmental terms, China ranks last with a 20% efficiency score, exacerbated by a vertically managed administrative system that prioritises economic growth over environmental standards (Chai et al. 2021). Addressing the role of FDI in pollution is critical for environmental improvement (Azam et al. 2019; Chai et al. 2021). Despite efforts to reduce emissions, China's environmental policies lag behind its rapid industrial growth, resulting in significant inefficiencies. From 2001 to 2007, China had a 21% efficiency score, which changed only marginally over the years, indicating persistent environmental challenges (Santana et al. 2014). The continuous low ranking, despite slight improvements in the score, underscores the need for more robust environmental strategies. Socially, China faces substantial challenges in addressing poverty, inequality and labour market distortions, which contribute to its last-place social efficiency ranking with a score of 57% (Ebenstein et al. 2015). Rapid urbanisation and economic reforms have created disparities, and the COVID-19 pandemic has further highlighted these social issues. The social efficiency score of 56% during 2001 to 2007, remaining relatively stagnant, points to enduring social challenges that have not been effectively addressed over the years (Santana et al. 2014). The exacerbation of social issues due to the pandemic and economic disruptions from the war has further stressed China's social infrastructure, necessitating comprehensive social reforms and targeted interventions (Gebert and de Mello-Sampayo 2025).

South Africa, despite having the lowest inputs and outputs among BRICS nations, has achieved notable efficiency across all domains. Its economic efficiency, averaging 68.16% during the 2010–2023 period, suggests significant potential for growth through enhanced FDI and R&D (Makhoba et al. 2019; Sunde 2016; Quaynor et al. 2022). Compared with the findings of Santana et al. (2014), South Africa's economic efficiency rank has fallen, but the percentage has grown slightly from 66% (second) in 2001–2007 to 68% (fifth) in 2010–2023, reflecting challenges but also highlighting opportunities for improvement. This period was also marked by global economic pressures and geopolitical conflicts, such as the impacts of the COVID-19 pandemic and ongoing regional conflicts, which have influenced economic activities and demanded adaptive strategies (Udi et al. 2020; WHO Africa 2022; Bekun et al. 2019).

Environmental leadership is evident in South Africa's top ranking, with a 98% efficiency score. This performance reflects the lowest CO_2 outputs among BRICS nations and demonstrates the positive impact of optimised inputs on environmental quality (Udi et al. 2020). South Africa's consistent environmental efficiency, 99% (first) in 2001–2007 and 98% (first) in 2010–2023, underscores its commitment to sustainable practices and effective environmental policies. Additionally, the role of innovative environmental policies and the global emphasis on climate change mitigation have reinforced these gains, positioning South Africa as a model for environmental sustainability in the Global South

(The World Bank 2018c). However, it is important to note that during this period, South Africa's energy sector faced significant challenges. While South Africa's low CO_2 outputs are commendable, they are partly a result of energy supply issues (Ayamolowo et al. 2022). Therefore, while the data highlight South Africa's environmental efficiency, they also underscore the need for a more resilient and reliable energy infrastructure to sustain these gains (Bekker et al. 2008).

Socially, South Africa's high efficiency score of 95.57% is attributed to substantial improvements in health and social services, despite a relatively low life expectancy of around 64 years. These gains can be linked to targeted health interventions and policies promoting inclusive growth (WHO Africa 2022; Francis and Webster 2019; The World Bank 2018c). The COVID-19 pandemic underscored the importance of resilient social policies to maintain these achievements, demonstrating the country's ability to adapt and improve its social infrastructure under pressure. The sustained focus on health infrastructure and social equity has proven essential in navigating the challenges posed by both the pandemic and other socioeconomic pressures (Francis and Webster 2019).

The second-stage Tobit regression confirms a statistically significant and positive relationship between NDB disbursements and DEA efficiency scores in BRICS countries post-2015. This result suggests that financial support from the NDB has likely contributed to improvements in countries' ability to transform inputs into sustainable development outcomes. This effect is particularly notable in India and Brazil, major recipients of NDB funding in infrastructure and social sectors. The significant role of NDB disbursements in improving efficiency scores aligns with recent findings on South–South development finance. As Banik and Mawdsley (2023) note, institutions like the NDB increasingly act not only as financial platforms but also as instruments of geopolitical and development influence among emerging economies.

6 | Conclusions

The study provides a comprehensive analysis of the BRICS countries' economic, environmental and social efficiencies over the period from 2010 to 2023, highlighting both progress and challenges. Economically, Brazil's average efficiency score of 83% places it second among BRICS nations, showing potential for growth through better FDI utilisation and refined fiscal policies. However, the fall from its first-place position in the 2001–2007 period underscores ongoing challenges. Policy implications for Brazil include stabilising economic strategies and addressing vulnerabilities exposed by global disruptions such as the COVID-19 pandemic and the war in Ukraine. Emphasis should be placed on enhancing GDP output through efficient resource allocation and adaptive fiscal policies.

Russia's economic performance has remained robust, maintaining the top efficiency ranking with an average score of 94%. This is significantly higher than its past performance, reflecting effective use of human capital and infrastructure development. Despite geopolitical tensions and economic pressures, Russia's economic strategies have proven resilient. Future policies should focus on sustaining this efficiency by continuing to invest in human capital and infrastructure while mitigating the impacts of geopolitical conflicts.

India, while showing improvement from previous periods, still faces challenges with an average economic efficiency score of 69%. The premature deindustrialisation and the pandemic's impact have hindered its growth. Policy implications for India involve fostering industrial growth alongside service sector expansion and improving healthcare and social support systems to enhance resilience against global disruptions.

China's economic efficiency, averaging 70%, highlights difficulties in leveraging its vast economic inputs effectively. The slight improvement from earlier periods is overshadowed by other BRICS nations' more effective strategies. Policies should focus on balancing economic growth with social and environmental improvements, addressing labour market distortions and mitigating the impacts of trade wars and geopolitical conflicts.

South Africa, despite its low inputs and outputs, has achieved notable efficiency, particularly in the environmental domain with an average score of 98%. The country's high efficiency scores across all dimensions suggest significant potential for growth through enhanced FDI and R&D. Policy implications for South Africa include sustaining its environmental leadership through innovative policies and further improving economic and social efficiencies by addressing structural vulnerabilities.

Environmental efficiency findings reveal that South Africa and Russia lead with high efficiency scores, underscoring their commitment to sustainable practices. Brazil's consistent but challenged environmental efficiency highlights the need for targeted policies to reduce deforestation and emissions. India and China face significant environmental challenges, calling for robust policies to improve their environmental footprints. Social efficiency trends indicate South Africa's leading position due to targeted health and social policies, while Russia and Brazil show substantial social improvements. India and China need to address their social policy gaps to improve life expectancy and reduce inequalities. The exacerbation of social issues due to the pandemic and economic disruptions further emphasises the need for comprehensive social reforms in these countries.

In addition to traditional input–output efficiency assessments, this study highlights the complementary role of institutional support, specifically from the NDB, in enhancing sustainable development outcomes. By incorporating NDB disbursement data into a second-stage regression framework, we find evidence that such multilateral financial flows positively affect national efficiency. Future research should further explore how institutional cooperation among emerging economies, such as BRICS, shapes the effectiveness of development strategies.

Data Availability Statement

The data that support the findings of this study are openly available in Data paper revised at https://figshare.com/account/items/26317636/edit, reference number 10.6084/m9.figshare.26317636.

Endnotes

[1] To incorporate the undesirable nature of CO_2 emissions into the DEA framework, the emission data were transformed by multiplying the data by −1 and adding a translation vector, ensuring that the transformed values remained positive without altering their relative positions.

[2] In terms of Foreign Direct Investment (FDI) for China, the data presented by the World Bank exclude Hong Kong SAR, Macao SAR, and Taiwan. Given that Hong Kong and Taiwan are major investors in China, both directly and as intermediaries, this exclusion has been taken into consideration. To ensure the accuracy and relevance of our analysis, we have factored in the significant FDI contributions from these regions through alternative data sources and adjustments.

[3] Detailed annual disbursement figures per country are not fully disclosed; the NDB's 2023 Annual Report provides cumulative outstanding disbursements as of December 31, 2023. We estimated the annual disbursements by subtracting the 2023 disbursement from the total outstanding amount and distributing the remainder evenly across the years 2016 to 2022 (assuming minimal or no disbursements in 2015).

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