Pol. J. Environ. Stud. Vol. XX, No. X (XXXX), 1-13
DOI: *10.15244/pjoes/201939* ONLINE PUBLICATION DATE:

Original Research

The Role of Sustainable Development in Emerging Economies: An Examination of Environmental and Economic Indicators

Luan Vardari, Isuf Qabrati°*, Vesel Usaj

University "Ukshin Hoti" Prizren, Faculty of Economics, Prizren, Kosovo

Received: 14 February 2024
Accepted: 1 February 2025

Abstract

Efficient use of financial and natural resources is crucial for mitigating environmental damage and fostering economic growth, particularly in emerging economies. Grounded in the theoretical framework of sustainable development and environmental Kuznets curve (EKC), this study examines the dual impact of renewable and non-renewable energy consumption on economic growth and greenhouse gas emissions in six BRICS countries – South Africa, Brazil, India, China, Russia – and Turkey from 2000 to 2022. We apply a dynamic panel data analysis that integrates resource-based theory and endogenous growth theory, employing descriptive analysis, correlation, and econometric model tests to analyze the cross-sectional dependency between natural resource development, financial development, globalization, economic growth, and emissions. Acknowledging the limitation of aggregate data, which may obscure regional or sectoral variations, the study uncovers that renewable energy positively impacts both economic growth and environmental sustainability, while non-renewable energy and globalization contribute to environmental degradation. The findings underscore that economic growth, globalization, and financial advancements are influenced by energy consumption patterns, with renewable energy offering a pathway to sustainable prosperity. Policy recommendations emphasize expanding renewable energy investments and adopting adaptive economic strategies to harmonize growth with environmental protection in the BRICS countries.

Keywords: financial developments, BRICS, energy consumption, economic growth

Introduction

Since the 1950s, eco-friendly deterioration has been regarded as the primary barrier to long-term development. It presents several ecological problems, such as high levels of pollution, global warming, water scarcity, deforestation, and climate change, all of which have turned into serious dangers. Therefore, efforts to solve the environmental issues brought on by human activity are being made in both developing countries and developed countries [1]. Because it is recognized as a global trend, reducing the effects of climate change has become a significant priority for many policy initiatives. Its significance is in supporting sustainable industrial processes, which are essential for human survival [2]. Environmental variations are now one of the most

*e-mail: isuf.qabrati@uni-prizren.com
Tel.: +38349351168
°ORCID iD: 0000-0002-9502-9070

urgent and continuous fears because of the destructive effects of extreme weather patterns and global warming. The increase in greenhouse gas (GHG) emissions is mostly to blame for this, and air pollution has also been related to human ailments such as lung cancer, bronchitis, pneumonia, and cerebral health issues [3, 4]. The usage of finite energy resources is increasing greenhouse gas release and hastening the effects of global warming. The usage of sustainable resources is not given priority by the current GDP growth rate. The necessity for finite energy resources, a key contributor to environmental degradation, has risen in tandem with rising GDP and resource depletion, raising questions about the long-term sustainability of this growth path [5]. Environmentalists and policymakers around the world are debating the relationship between GDP growth, power use, financial development, ecological issues, and globalization, raising questions about sustainability.

By creating linkages across the political, cultural, social, and economic spheres, globalization – which is defined as the interconnectivity of enterprises and economic cooperation among nations – has aided in fostering economic progress. However, despite its role in fostering industrialization, the additional energy consumption that comes with it has had a negative effect on the environment [6, 7]. Greenhouse gas (GHG) emissions have increased annually by 2.7% because of globalization, greatly accelerating climate change. Environmental quality has been significantly damaged by carbon dioxide (CO_2) discharges, which account for around 60% of GHG emissions [8]. However, those who support globalization consider the deterioration of the environment as a cost of economic expansion. On the other hand, by fostering commerce and foreign investment, globalization has improved the economy [9, 10]. Environmental degradation is mostly caused by excessive economic growth that depletes natural resources. Resources, including coal, oil, and gas, have been extracted more than twice as much in the last six years – from 6.1 billion tons to 15.1 billion tons. The amount of biomass produced has doubled from 9 billion to 24 billion tons, while the number of mineral resources extracted has multiplied five times. Humans extract over 60 billion tons of natural resources annually, up 50% from 30 years ago [11].

Strong institutions serve as the cornerstone for a nation's economic development and, as observation demonstrates, contribute to a strong nation. Institutional variations are the main cause of regional growth discrepancies. Natural resources in a country have two different kinds of impacts: institutional influence and output effect [12, 13]. It is well known that nations with abundant natural resources frequently have less developed economies than nations with fewer resources but more robust economies. Natural resources are distributed unevenly throughout China, with some provinces and coastal regions, like Jiangsu, investing in public education and the development of both natural and human resources to boost industrial output. The Dutch disease model and institution quality are the two primary hypotheses that have been advanced to explain this phenomenon [6, 14]. China, Russia, India, and Brazil have set plans to employ renewable energy sources by the year 2020. Considering the complete manufacturing capacity and the planned role of renewables in total power production, these aims are important in terms of overall installed capacity and energy production [15, 16]. Reduced CO_2 emissions and less dependency on foreign energy sources are two of these nations' main goals in developing renewable energy. In the ensuing decades, this entails decoupling rising fossil fuel consumption from economic growth [15]. It is anticipated that this separation will help improve the water and air quality in the nearby areas. Between 1995 and 2003, environmental degradation cost the country more than 4% of its GDP, according to estimates by [16]. As the world's top supplier of low-cost, in-demand clean energy machinery, the advancement of renewable energy also aims to boost China's competitiveness [17-19]. Our main objective is to assess how BRICS's renewable energy targets will affect the usage of remnant fuels and renewable energy sources, as well as how they will affect CO_2 emissions. For politicians worldwide and in China, this is essential. Understanding worries about the depletion of natural resources is crucial for Brazil, China, South Africa, India, and Turkey from 2000 to 2022.

The United Nations (UN) member nations have ratified the 2015 Sustainable Development Goals (SDGs), which call for them to support steady monetary growth, efficient power use, responsible resource management, and the resolution of urgent environmental issues. Energy, as a necessary component of manufacturing, is essential to the growth of world economies [16]. Because of this, the expenditure of non-renewable and renewable energy has been essential for promoting environmental sustainability and economic growth. Separating environmental damage from the connection between economic energy and growth use is crucial [17].

The economies of the BRICS nations – Russia, Brazil, China, India, South Africa, and Turkey – are among the top ten energy consumers and producers in the world. In recent decades, the BRICS economies have progressively boosted their use of renewable energy. However, there are large differences in how often renewable energy is used between BRICS economies [5, 14, 18]. In 2018, Brazil accounted for 43.79% of the world's final gross energy consumption, followed by India accounted for 36.02%, South Africa accounted for 17.15%, China accounted for 12.41%, and Russia accounted for 3.30% [10, 11, 19, 20].

Anton et al. [18] held the opinion that a nation's financial situation affects the development of renewable energy sources (REC). However, despite financial and economic considerations, other factors, including geography and domestic circumstances, may also contribute to discrepancies. Brazil, for instance, is one of the BRICS nations with the most forested land,

and hydroelectric power accounts for 63.8% of its total renewable energy production, followed by biomass and biogas accounted for 8.9%, wind accounted for 9.3%, and centralized solar accounted for 1.4%. Russia, in comparison, has a huge landmass, a small population, and abundant mineral resources. With a 22 GW capacity, India's wind energy industry is the fifth largest in the world. China's circular economy standard, which encourages the responsible use and renewal of organic resources through reduction, reuse, and recycling, may be the reason why its hydroelectric and wind power sectors are growing more quickly than those of other nations [21, 22].

For several reasons, this analysis concentrates on the BRICS nations. First off, these nations currently account for 40% of the globe's energy consumption and 21% of the globe's GDP combined. They also have half of the world's population. Second, from 1990 to 2018, the GDP of these BRICS nations increased from 4,985 billion US dollars (constant 2010) to 7,719 billion US dollars, making them the world's leaders in economic growth over the previous two decades. Additionally, investment in these nations is rising quickly [23]. The study also reflects the effects of environmental innovation on power productivity and REC, which have not been sufficiently covered in earlier studies. Thirdly, by concentrating on the BRICS economies, this study offers insightful information about the connections between financial globalization, economic growth, environmental innovation, and REC in quickly expanding and developing economies. This information is crucial for policymakers and stakeholders in the energy sector. The research's conclusions can guide future energy policy decisions in these economies to maintain sustainable economic growth and prevent environmental damage [23].

Materials and Methods

A balanced longitudinal data set of six BRICS nations – South Africa, Brazil, India, China, Russia, and Turkey – from 2000 to 2022 was used to investigate the impact of renewable and non-renewable energy, natural resource use, monetary advancement, globalization, and economic progress on greenhouse gas (GHG) emissions and economic growth. While real economic growth was assessed in constant 8571 US dollars per person, the complete environmental indicator, greenhouse gas emissions, was calculated in k-tons of carbon dioxide equivalent. The total of coal, oil, natural gas, forest, and mineral rents, expressed as a percentage of GDP, was used to determine natural resource prices. Globalization, financial development, finite energy resources consumed per person in kilograms of oil equivalent, and the consumption of renewable power as a percentage of total energy use were all measured on a scale from 0 to 100. Environmental damage and monetary growth were measured, respectively, using the metrics of greenhouse gas emissions and gross domestic product (GDP). The database of the World Bank served as the primary source of the data. The International Monetary Fund (IMF) and Dreher [24] (2006), correspondingly, are the sources of the data for FD and GLO [24-26].

The data analysis was done in STATA to analyze the relationships between renewable and non-renewable energy consumption, economic growth, and greenhouse gas emissions in BRICS countries and Turkey. Descriptive statistics were used to determine the means, standard deviations, minimum and maximum for GHG emissions, natural resource rent (%) of GDP, economic growth, non-renewable energy use, and monetary advancement for India, Brazil, South Africa, Russia, China, and Turkey. Correlation analysis was used to determine the relationship between GHG emissions, natural resource rent (%) of GDP, non-renewable energy use, monetary advancement, and economic growth. To ensure the reliability of our time series data, we apply panel unit root tests. Following this, the cointegration test is used to assess the presence of long-term equilibrium relationships between the variables. The absence of cointegration suggests that short-term dynamics may dominate these relationships, which is further explored through subsequent econometric analyses. This methodological approach ensures a robust analysis of the energy-economy-environment nexus in the selected countries. Lastly, an econometric model was employed to determine the impact of GHG emissions, natural resource rent (%) of GDP, non-renewable energy use, and monetary advancement on economic growth. The model was specified by the equation that follows:

Where is the error term for the model, the model intercept, and the model parameters explaining the effect of GHG emissions, natural resource rent (%) of GDP, non-renewable energy use, and monetary advancement on economic growth? Inferences were made at a 5% level of significance in determining the variables that were statistically significant and those that were not.

Results and Discussion

Empirical Analysis

The analysis of GHG emissions across BRICS countries from 2000 to 2022 reveals significant disparities in emission levels and trends (Table 1). China and India, with their rapid industrial growth and heavy reliance on fossil fuels, show substantial increases in emissions. Conversely, Brazil, South Africa, Russia, and Turkey maintain lower and more stable emission levels, reflecting diverse energy policies and consumption patterns. This analysis underscores the necessity for tailored, country-specific strategies to mitigate emissions and promote sustainable development effectively.

According to the summary statistics, China had the highest number of emissions from 2000-2022, followed by India, Russia, South Africa, Brazil, and Turkey, which had the lowest on average. The changes in terms of the levels of GHG emissions revealed the levels of environmental pollution in the BRIC countries.

As illustrated in Table 2, the average use of renewable energy varied significantly between the BRICS countries and other selected countries during the study period. South Africa led the group with an impressive 45.08% of its energy consumption that comes from renewable sources. Brazil followed closely with 38.76%, reflecting its extensive investment in bioenergy and hydropower. In contrast, India recorded a much lower average share of renewable energy at 11.55%, despite its recent efforts to expand solar and wind power capacity. China, the world's largest energy consumer, had an average renewable energy share of just 5.23%, highlighting the country's continued reliance on coal and other non-renewable sources. Turkey had the smallest proportion of renewable energy among the surveyed countries, at only 0.068%, highlighting the need for significant policy changes to improve its renewable energy infrastructure. These differences highlight the different energy landscapes and the challenges each country faces in transitioning to sustainable energy practices.

Regarding non-renewable energy use, Brazil was the leading country with an average of 27.47%, followed closely by South Africa at 21.58%. China came third at 8.22%. Russia at 0.45% and Turkey at 0.05% had the least amounts of non-renewable energy use (Table 3).

In terms of the natural resource rent (%) of GDP, the findings reported the highest proportions being Turkey at 35.58%, followed by Russia on average. Russia at 14.82%, China at 3.85%, and Brazil at 3.19% had the least natural resource rents (%) of GDP over the years (Table 4).

According to the findings, China was the leader in terms of monetary development (Table 5). This was followed by South Africa, Turkey, Brazil, India and Russia in that order. The trend revealed that Russia had

Table 1. Descriptive Statistics for GHG emissions.

Variable	Obs	Mean	Std. Dev.	Min	Max
India	22	1793.578	578.573	994.863	2648.779
South Africa	22	439.529	39.554	346.602	485.757
Brazil	22	444.614	62.684	364.752	559.342
Turkey	22	323.113	77.895	206.579	449.725
China	22	8706.838	2879.09	3703.34	12466.316
Russia	22	1756.149	68.359	1655.375	1942.535

Table 2. Descriptive Statistics for renewable energy use.

Variable	Obs	Mean	Std. Dev.	Min	Max
India	20	11.549	1.828	9.77	16.25
South Africa	20	45.08	2.154	41.33	48.92
Brazil	20	38.756	5.504	32.41	47.11
Turkey	20	.068	.014	.05	.09
China	20	5.232	4.189	.18	16.61
Russia	20	3.4	.167	3.18	3.67

Table 3. Descriptive Statistics for non-renewable energy use.

Variable	Obs	Mean	Std. Dev.	Min	Max
India	15	7.868	.45	7.072	8.702
South Africa	15	21.575	1.374	19.036	23.741
Brazil	15	27.47	4.093	21.374	32.766
Turkey	15	.046	.011	.026	.058
China	15	8.218	4.872	2.883	17.272
Russia	15	.449	.068	.36	.572

Table 4. Descriptive Statistics for natural resource rents (%) of GDP.

Variable	Obs	Mean	Std. Dev.	Min	Max
India	22	5.257	2.03	2.808	11.99
South Africa	22	3.438	1.246	2.159	7.941
Brazil	22	3.19	1.336	1.748	7.109
Turkey	20	35.577	18.616	9.658	75.366
China	22	3.485	2.421	.864	9.648
Russia	22	14.816	3.756	7.588	21.503

Table 5. Descriptive Statistics for monetary advancement.

Variable	Obs	Mean	Std. Dev.	Min	Max
India	22	45.348	8.442	28.34	54.652
South Africa	22	61.522	4.723	50.128	70.384
Brazil	22	50.212	15.622	27.686	71.442
Turkey	18	56.7	21.191	.186	85.056
China	22	133.511	23.997	102.004	182.868
Russia	21	41.619	13.598	16.838	59.732

the least monetary advancement, which was closer to Indian values.

The analysis informed that China had the highest GDP growth over the years at 8.67%. This was followed by Turkey at 8.07%, India at 5.96%, Russia at 3.51%, South Africa at 2.37, and the least, Brazil at 2.23% on average (Table 6).

The results of the regression reveal significant differences in the impact of monetary progress, the use of natural resources, non-renewable energy, renewable energy, and greenhouse gas emissions in the five BRICS countries (Table 7). In Brazil and South Africa, the use of natural resources has a significant positive impact on economic indicators. In contrast, the use of renewable energy has a positive effect in South Africa but not in Brazil. Monetary progress has a negative impact on Russia and China, with significant results indicating a possible negative impact on environmental outcomes. Conversely, the use of non-renewable energy shows mixed and mostly insignificant effects in all countries. Greenhouse gas emissions have a significant negative effect in South Africa but a positive effect in Russia, reflecting different environmental dynamics. The R-squared values show that the models explain significant variance in South Africa and Russia, but less so in India. These results emphasize the need for country-specific policy approaches to reconcile economic growth and environmental sustainability in the BRICS countries.

According to the analysis, the models for the different countries can be defined as:

For South Africa

$$ED = 7.34 - 0.05 * Monedev + 2.1 * Naturalres + 0.01 * nonrenew + 0.19 * renew - 0.04 * GHG$$

Table 6. Descriptive Statistics for GDP growth.

Variable	Obs	Mean	Std. Dev.	Min	Max
India	22	5.962	3.315	-6.596	8.681
South Africa	22	2.366	2.664	-6.342	5.604
Brazil	22	2.232	3.052	-3.879	7.528
Turkey	20	8.07	3.859	.257	14.7
China	22	8.665	2.487	2.24	14.231
Russia	22	3.512	4.132	-7.8	10

Table 7. Determinants of economic growth in BRICS countries.

Variables	(1) South Africa	(2) Brazil	(3) India	(4) Russia	(5) China
Monetary advancement	-0.0489	-0.287	-0.00318	-0.252***	-0.144**
	(0.0748)	(0.173)	(0.220)	(0.0708)	(0.0664)
Natural resource use	2.100***	1.509***	-0.0849	-0.151	-0.150
	(0.353)	(0.484)	(0.478)	(0.291)	(0.355)
Non-renewables	0.0112	-0.0192	0.237	2.698	-0.230
	(0.0398)	(0.0834)	(0.434)	(4.632)	(0.310)
Renewables	0.187***	-0.114	0.369	0.887	-0.195
	(0.0362)	(0.0917)	(0.284)	(0.663)	(0.147)
GHG emissions	-0.0387***	0.0378	0.00232	0.0480***	0.000161
	(0.0108)	(0.0291)	(0.00428)	(0.0127)	(0.000851)
Constant	7.335	-0.565	-2.757	-72.08***	29.23***
	(4.604)	(5.482)	(7.733)	(20.15)	(8.562)
Observations	22	22	22	22	22
R-squared	0.780	0.589	0.147	0.758	0.712

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

The findings informed that monetary development (β = -0.15) and GHG emissions (β = -0.04) had a negative effect on economic growth. Nonetheless, natural resource (β = 2.1), non-renewable energy use (β = 0.01), and renewable energy use (β = 0.19) had a positive effect on economic growth. The analysis informed that natural resource rent (%) of GDP, renewable energy use and GHG emissions had a significant effect on economic growth.

For Brazil

$$ED = -0.565 - 0.29 * Monedev + 1.51 * Naturalres - 0.02 * nonrenew - 0.01 * renew + 0.04 * GHG$$

The analysis showed that monetary development (β =-0.29), non-renewable energy use (β =-0.02), and renewable energy use (β =-0.01) had a negative effect on economic growth. However, GHG emissions (β = 0.04) and natural resource (β = 2.1) had a positive effect on economic growth. The analysis informed that only GHG emissions and monetary development had a significant effect on economic growth.

For India

$$ED = -2.757 - 0.0032 * Monedev - 0.0849 * Naturalres + 0.237 * nonrenew + 0.369 * renew + 0.002 * GHG$$

The analysis showed that monetary development (β=-0.08) and natural resources (β=-0.085) had a negative effect on economic growth. However, non-renewable energy use (β = 0.237) and renewable energy use (β = 0.369), GHG emissions (β = 0.02) and had a positive effect on economic growth. The analysis informed that none of the variables had a significant effect on economic growth.

For Russia

$$ED = -72.08 - 0.25 * Monedev - 0.151 * Naturalres + 2.698 * nonrenew + 0.887 * renew + 0.048 * GHG$$

The findings informed that monetary development (β = -0.25) and natural resource rent (%) of GDP (β = -0.151) had a negative effect on economic growth. Nonetheless, GHG emissions (β = 0.048), non-renewable energy use (β = 2.698), and renewable energy use (β = 0.048) had a positive effect on economic growth. The analysis informed renewable energy use and GHG emissions had a significant effect on economic growth.

For China

$$ED = 29.23 - 0.14 * Monedev - 0.15 * Naturalres - 0.230 * nonrenew - 0.195 * renew - 0.0002 * GHG$$

According to the result, monetary development (β = -0.14), non-renewable sources (β = -0.195) and renewable energy use (β =-0.195), GHG emissions (β = -0.0002), and natural resource rent (%) of GDP (β = -0.15) and natural resource rent (%) of GDP (β = -0.15) had a negative effect on economic growth across BRICS countries.

Correlation Analysis

The analysis revealed that monetary advancement (r = -0.079) and GHG emissions (r = -0.198) had a negative relationship with economic growth. Natural resource rent (r=0.308), non-renewables (r = 0.480), and renewables (r = 0.358) had a positive relationship with economic growth in South Africa (Table 8).

The findings showed that monetary advancement (r = -0.426) and GHG emissions (r = -0.337) had a negative relationship with economic growth. Natural resource rent (r = 0.647), non-renewables (r = 0.564), and renewables (r = 0.132) had a positive relationship with economic growth in Brazil (Table 9).

The findings informed that monetary advancement (r = -0.089), GHG emissions (r = -0.102), and natural resource rent (r = -0.042) had a negative relationship with economic growth. However, non-renewables (r = 0.178) and renewables (r = 0.324) had a positive relationship with economic growth in India (Table 10).

The analysis informed that monetary advancement (r = -0.790), renewables (r = -0.171), and GHG emissions (r = -0.536) had a negative relationship with economic growth. However, natural resource rent (r = 0.670) and non-renewables (r = 0.476) had a positive relationship with economic growth, as witnessed in the analysis (see Table 11).

In Russia, monetary advancement (r = -0.671) had a negative relationship with economic growth. However, natural resource rent (r = 0.696), non-renewables (r = 0.527), renewables (r = 0.220), and GHG emissions (r = 0.095) had a positive relationship with economic growth (Table 12).

Table 8. Pairwise correlations for South Africa.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
(1) Economic Growth	1.000					
(2) Monetary advancement	-0.079	1.000				
	(0.728)					
(3) Natural resource rent	0.308	0.082	1.000			
	(0.164)	(0.717)				
(4) Non-renewables	0.480	0.176	-0.091	1.000		
	(0.024)	(0.432)	(0.689)			
(5) Renewables	0.358	0.145	-0.523	0.443	1.000	
	(0.102)	(0.520)	(0.012)	(0.039)		
(6) GHG emissions	-0.198	0.377	0.300	-0.216	0.132	1.000
	(0.378)	(0.084)	(0.176)	(0.334)	(0.558)	

Table 9. Pairwise correlations for Brazil.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
(1) Economic Growth	1.000					
(2) Monetary advancement	-0.426	1.000				
	(0.048)					
(3) Natural resource rent	0.647	-0.122	1.000			
	(0.001)	(0.588)				
(4) Non-renewables	0.564	-0.808	0.464	1.000		
	(0.006)	(0.000)	(0.030)			
(5) Renewables	0.331	-0.754	0.180	0.713	1.000	
	(0.132)	(0.000)	(0.422)	(0.000)		
(6) GHG emissions	-0.337	0.906	-0.089	-0.659	-0.473	1.000
	(0.125)	(0.000)	(0.694)	(0.001)	(0.026)	

Table 10. Pairwise correlations for India.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
(1) Economic Growth	1.000					
(2) Monetary advancement	-0.089	1.000				
	(0.695)					
(3) Natural resource rent	-0.042	0.270	1.000			
	(0.853)	(0.225)				
(4) Non-renewables	0.178	-0.510	0.299	1.000		
	(0.428)	(0.015)	(0.177)			
(5) Renewables	0.324	-0.625	-0.100	0.588	1.000	
	(0.141)	(0.002)	(0.658)	(0.004)		
(6) GHG emissions	-0.102	0.832	-0.063	-0.816	-0.667	1.000
	(0.650)	(0.000)	(0.779)	(0.000)	(0.001)	

Table 11. Pairwise correlations for China.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
(1) Economic Growth	1.000					
(2) Monetary advancement	-0.790	1.000				
	(0.000)					
(3) Natural resource rent	0.670	-0.701	1.000			
	(0.001)	(0.000)				
(4) Non-renewables	0.476	-0.756	0.211	1.000		
	(0.025)	(0.000)	(0.346)			
(5) Renewables	-0.171	0.117	0.009	-0.457	1.000	
	(0.448)	(0.603)	(0.968)	(0.033)		
(6) GHG emissions	-0.536	0.787	-0.244	-0.979	0.505	1.000
	(0.010)	(0.000)	(0.273)	(0.000)	(0.017)	

Table 12. Pairwise correlations for Russia.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
(1) Economic Growth	1.000					
(2) Monetary advancement	-0.671	1.000				
	(0.001)					
(3) Natural resource rent	0.696	-0.756	1.000			
	(0.000)	(0.000)				
(4) Non-renewables	0.527	-0.798	0.708	1.000		
	(0.012)	(0.000)	(0.000)			
(5) Renewables	0.220	-0.439	0.210	0.533	1.000	
	(0.324)	(0.041)	(0.349)	(0.011)		
(6) GHG emissions	0.095	0.516	-0.065	-0.521	-0.595	1.000
	(0.673)	(0.014)	(0.773)	(0.013)	(0.003)	

In Turkey, natural resource rent (r = -0.033) and renewables (r = -0.394) had a negative relationship with economic growth. Nonetheless, monetary advancement (r = 0.295), non-renewables (r = 0.040), and GHG emissions (r = 0.181) had a positive relationship with economic growth (Table 13).

The fixed effect regression model in Table 14 reveals key insights into the impact of monetary advancement, natural resource use, non-renewables, GHG emissions, and renewables on the dependent variable. Monetary advancement shows a positive but insignificant effect, suggesting that it does not play a crucial role in this context. In contrast, natural resource use and non-renewables significantly increase the dependent variable with coefficients of 0.07 and 0.265, respectively, indicating that these factors contribute positively and significantly. GHG emissions have a marginal yet significant positive impact at the 10% level. Notably, renewable energy use has a significant negative effect, with a coefficient of -0.204, highlighting its role in reducing the dependent variable. The model's overall R-squared value of 0.333 implies that the variables explain approximately 33.3% of the variance in the dependent variable, and the highly significant Chi-square value (Prob > chi2 = 0.000) confirms the model's robustness.

The cross-sectional dependence test results in Table 15 reveal significant dependencies among several series. The Breusch-Pagan LM test indicates significant cross-sectional dependence for FD, natural resource use, non-renewables, GHG emissions, and renewables, with all p-values below 0.05, except for monetary advancement (p-value = 0.2004). The Pesaran CSD test further confirms these dependencies, showing significant results for FD, natural resource use, non-renewables, and GHG emissions with p-values of 0.0000, while monetary advancement and renewables do not show significant dependence (p-values of 0.1248 and 0.4187,

Table 13. Pairwise correlations for Turkey.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
(1) Economic growth	1.000					
(2) Monetary advancement	0.295	1.000				
	(0.207)					
(3) Natural resource rent	-0.033	0.401	1.000			
	(0.891)	(0.080)				
(4) Non-renewables	0.040	0.557	0.819	1.000		
	(0.866)	(0.011)	(0.000)			
(5) Renewables	-0.394	0.238	0.787	0.798	1.000	
	(0.086)	(0.313)	(0.000)	(0.000)		
(6) GHG emissions	0.181	-0.522	-0.861	-0.915	-0.803	1.000
	(0.444)	(0.018)	(0.000)	(0.000)	(0.000)	

Table 14. Findings of Fixed Effect.

FD	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Monetaryadvancement	.009	.015	0.57	.572	-.021	.039	
Naturalresourceuse	.07	.031	2.29	.022	.01	.13	**
NonRenewables	.265	.076	3.47	.001	.115	.414	***
GHGEmissions	0	0	1.68	.094	0	.001	*
Renewables	-.204	.042	-4.82	0	-.286	-.121	***
Constant	3.994	.991	4.03	0	2.052	5.936	***
Overall r-squared	0.333		Prob > chi2	0.000			
Chi-square	62.975						

*** p<.01, ** p<.05, * p<.1

respectively). These findings underscore the presence of cross-sectional dependencies in most examined variables, highlighting the interconnected nature of these factors across different cross-sections.

The panel stationary tests demonstrated in Table 16 indicate the stationarity properties of various series at the level and first difference. Using the CADF and CIPS tests, all series – FD, monetary advancement, natural resource use, non-renewables, GHG emissions, and renewables – are discovered to be non-stationary at the level, as their test statistics do not meet the critical values at the 1%, 5%, or 10% significance levels. However, when tested at the first difference, all series become stationary, as indicated by the test statistics exceeding the critical values, confirming integration at order l (1). This means each series becomes stationary after first differencing, indicating that they are I (1) processes. This finding is crucial for further econometric modeling, ensuring that the variables do not exhibit unit roots, which could otherwise lead to spurious regression results.

In Table 17, the Westerlund co-integration test results assess the long-term equilibrium relationship within the financial development function. The test statistics (Gt, Ga, Pt, Pa) and their corresponding Z-values and P-values indicate no significant evidence of cointegration. Specifically, the P-values for Gt (0.329), Ga (0.998), Pt (0.726), and Pa (0.973) are all well above the common significance thresholds (0.01, 0.05, 0.10). This lack of significance suggests that the variables in the financial development function do not share a stable, long-term cointegrating relationship during

Table 15. Cross-sectional Dependence Test.

Series	Breusch-Pagan LM		Pesaran CSD	
	Statistics	Prob.	Statistics	Prob.
FD	47.42	0.0000	8.235	0.0000
Monetaryadvancement	1.64	0.2004	1.535	0.1248
Naturalresourceuse	8.28	0.0040	8.655	0.0000
NonRenewables	4.68	0.0306	7.207	0.0000
GHGEmissions	3.95	0.0470	13.178	0.0000
Renewables	4.08	0.0434	0.809	0.4187

Table 16. Panel Stationary Tests.

	Level		First Difference		Integration order
	CADF	CIPS	CADF	CIPS	
FD	-1.999	-2.200	-1.764	-4.769	l (1)
Monetaryadvancement	-2.184	-2.802	-1.464	-4.114	l (1)
Naturalresourceuse	-1.646	-2.229	-2.127	-5.327	l (1)
NonRenewables	-2.445	-3.113	-1.692	-4.068	l (1)
GHGEmissions	-1.975	-1.609	-1.960	-3.142	l (1)
Renewables	-1.937	-1.750	-2.134	-3.573	l (1)
Critical values	1% 5% 10%		1% 5% 10%		l (1)
	-2.21 -2.33 -2.57		-2.21 -2.34 -2.6		

Table 17. Westerlund Cointegration Test.

Statistics	G_t	G_a	P_t	P_a
Financial Development function				
Values	-2.383	-2.592	-3.873	-1.803
Z-values	-0.443	2.913	0.602	1.919
P-values	0.329	0.998	0.726	0.973

Table 18. Long-run Elasticity Estimates (Financial Development function).

Variable	MG		AMG		CCEMG	
	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value
FD					0.7841062	0.000
Monetaryadvancement	0.8096749	0.036	0.5451964	0.119	-0.6435428	0.173
NonRenewables	1.350659	0.002	2.612056	0.123	2.432182	0.148
GHGEmissions	0.9676151	0.726	-0.0682764	0.972	-0.47562	0.675
Renewables	-2.305498	0.001	-4.836517	0.034	0.3868439	0.507
Constant	-6.19843	0.770	5.412999	0.754	-10.68752	0.323
RSME	0.4378		0.3160		0.2792	

the study period. Consequently, this finding implies that the relationship among the variables in the financial development context may be driven by short-term dynamics rather than long-term equilibrium factors.

The long-run elasticity estimates for the financial development function presented in Table 18 show varied impacts of different variables across three estimation methods: MG, AMG, and CCEMG. Financial development (FD) has a significant positive elasticity (0.7841062, p-value = 0.000) in the CCEMG model, indicating a strong long-term relationship. Monetary advancement shows a significant positive effect in the MG model (0.8096749, p-value = 0.036), but it is insignificant in the AMG and CCEMG models. Non-renewables exhibit significant positive elasticities in the MG model (1.350659, p-value = 0.002) but not in the AMG and CCEMG models. GHG emissions do not show significant long-run relationships in any of the models. Renewable energy use has a significant negative elasticity in the MG (-2.305498, p-value = 0.001) and AMG models (-4.836517, p-value = 0.034), but it is insignificant in the CCEMG model. The constants and RMSE values indicate variability in model fit and reliability, with the lowest RMSE in the CCEMG model (0.2792), suggesting a better fit compared to MG (0.4378) and AMG (0.3160). These results highlight the complex and context-dependent nature of long-term relationships between financial development and the examined variables.

Conclusions

According to the analysis, non-renewable use, renewable energy use, natural resource rent, GHG emissions and monetary advancement had various effects on economic growth across the BRIC countries. In South Africa, monetary development and GHG emissions had a negative effect on economic growth. Nonetheless, natural resources, non-renewable energy use, and renewable energy use have had a positive effect on economic growth. In Brazil, monetary development, non-renewable energy use and renewable energy use had a negative influence on economic growth. However, GHG emissions and natural resources had a positive impact on economic growth. In India, monetary development and natural resources had a negative impact on economic growth. However, GHG emissions, non-renewable energy use and renewable energy use had a positive effect on economic growth. In Russia, monetary development and natural resource rent (%) of GDP had a negative impact on economic growth. However, GHG emissions, non-renewable energy use and renewable energy use had a positive effect on economic growth. In China, monetary development, non-renewable use, renewable energy uses, natural resource rent (%) of GDP, and GHG emissions had a negative influence on economic growth.

The analysis across Tables 14 to 18 provides comprehensive insights into the dynamics between financial advancement, energy consumption, and greenhouse gas (GHG) emissions in the BRICS countries. Fixed effect regression in Table 14 indicates that natural resource use and non-renewables significantly increase economic outcomes, while renewable energy has a substantial negative effect, highlighting its role in reducing environmental impact. The cross-sectional dependence test in Table 15 confirms significant dependencies among most variables, underscoring the interconnected nature of economic and environmental factors. The panel stationary tests in Table 16 reveal that all variables achieve stationarity when differenced once, ensuring the reliability of further econometric analyses. However, the Westerlund cointegration test in Table 17 indicates no significant long-term cointegrating relationships, suggesting that short-term dynamics predominantly drive the relationships among the variables. This implies that the variables do not move together over the long term in a way that maintains a consistent relationship. The absence of long-term cointegration means that the relationships among the variables are not stable over the long term, suggesting that short-term factors are more influential. Lastly, the long-run elasticity estimates in Table 18 reveal that financial development significantly influences economic outcomes, with renewable energy showing a robust negative effect in some models.

In light of the results of the current study, the policymakers in these countries should adopt cleaner and alternative energy policies to solve many problems, such as global warming, climate change, energy transformation, and sustainable economic development. Due to the high dependence on non-renewable energy sources in most BRIC countries and Turkey, current energy supply and management regulations are proving ineffective in reducing greenhouse gas (GHG) emissions for the time being.

Therefore, these governments and central authorities should prioritize the use of clean and renewable resources such as wind, geothermal, hydro, biomass, solar, and photovoltaic energy, as well as the adoption of energy-efficient technologies. This change has the potential to slow down global warming, protect the environment, and promote sustainable economic growth. Moreover, supporting clean and renewable energy programs can have benefits such as regional economic development, employment opportunities, and technological improvements. A balanced investment in regional research and development (R&D) can help the region meet its renewable energy production goals. Increasing environmental awareness is essential to promote better energy options further. To promote environmental awareness and increase social acceptance of alternative energy sources, the government and central agencies should encourage public-private partnerships (PPPP).

It is important to consider certain constraints and assumptions when developing policies. The reliability and effectiveness of the policy framework could be compromised if these elements are ignored. First and foremost, governments should give priority to reducing crude oil imports by encouraging import substitution and replacement. This would mean increasing import taxes on petroleum-related goods and crude oil gradually. To decrease the exploitation of natural resources, strict laws and regulations to maintain environmental quality should be developed and strictly implemented.

Last but not least, the shift to a more environmentally friendly energy sector would put a strain on the production of traditional fossil fuels, which could lead to an increase in unemployment in this sector. To keep things balanced, the surplus workforce from the energy sector should receive proper job training so that they can participate in the growth of a more sustainable and clean energy sector. This strategy can support the growth of a sustainable economy.

In summary, while sustainable economic growth is essential for all economies, it is not sufficient by itself to ensure environmental protection. Central governments and policymakers in all arctic economies must take comprehensive action to reduce greenhouse gas emissions if they are to manage environmental pressures while promoting sustainable economic growth. The introduction, implementation, and diffusion of energy-efficient and zero-emission technologies should be part of these initiatives.

Acknowledgments

We would like to express our gratitude to all those who have contributed to this article. While no specific support or assistance was received, we are thankful for the inspiration and encouragement from colleagues and friends who helped shape our thoughts and ideas.

Conflict of Interest

The authors declare no conflict of interest.

References

1. OZCAN B., TZEREMES P., DOGAN E. Re-estimating the interconnectedness between the demand of energy consumption, income, and sustainability indices. Environmental Science and Pollution Research International. **26** (26), 26500, **2019**.
2. USMAN M., KHALID K., MEHDI M.A. What determines environmental deficit in Asia? Embossing the role of renewable and non-renewable energy utilization. Renewable Energy. **168**, 1165, **2021**.
3. YANG B., JAHANGER A., USMAN M., KHAN M.A. The dynamic linkage between globalization, financial development, energy utilization, and environmental sustainability in GCC countries. Environmental Science and Pollution Research. **28**, 16568, **2021**.
4. SONG C.Q., CHANG C.P., GONG Q. Economic growth, corruption, and financial development: Global evidence. Economic Modelling. **94**, 822, **2021**.
5. ULUCAK R., KOÇAK E., ERDOĞAN S., KASSOURI Y. Investigating the non-linear effects of globalization on material consumption in the EU countries: Evidence from PSTR estimation. Resources Policy. **67**, 101667, **2020**.
6. ZAFAR M.W., SAUD S., HOU F. The impact of globalization and financial development on environmental quality: evidence from selected countries in the Organization for Economic Co-operation and Development (OECD). Environmental Science and Pollution Research. **26**, 13246, **2019**.
7. JAHANGER A., USMAN M., BALSALOBRE-LORENTE D. Autocracy, democracy, globalization, and environmental pollution in developing world: Fresh evidence from STIRPAT model. Journal of Public Affairs. **22** (4), e2753, **2022**.
8. YOU W., ZHIKE L.V. Spillover effects of economic globalization on CO2 emissions: a spatial panel approach. Energy Economics. **73**, 248. **2018**.
9. AMNA INTISAR R., YASEEN M.R., KOUSAR R., USMAN M., MAKHDUM M.S. A. Impact of trade openness and human capital on economic growth: a comparative investigation of Asian countries. Sustainability. **12** (7), 2930, **2020**.
10. LATIF Z., LATIF S., XIMEI L., PATHAN Z.H., SALAM S., JIANQIU Z. The dynamics of ICT, foreign direct investment, globalization and economic growth: Panel

estimation robust to heterogeneity and cross-sectional dependence. Telematics and Informatics. **35** (2), 318, **2018**.

11. GILJUM S., HINTERBERGER F., BRUCKNER M., BURGER E., FRÜHMANN J., LUTTER S., WARHURST M. Overconsumption? Our use of the world's natural resources. Friends of Earth Europe. Available online: http://www.foeeurope.org/publications/2009/Overconsumption_Sep09.pdf (accessed on 08.10.2023). **2009**.
12. KHAN H., WEILI L., KHAN I. Institutional quality, financial development and the influence of environmental factors on carbon emissions: evidence from a global perspective. Environmental Science and Pollution Research. **29**, 13356, **2022**.
13. SONG Y., LIU J., WEI Y., ZHANG M. Study on the direct and indirect effectiveness of wind power policy: Empirical evidence from 30 provinces in China. Renewable Energy. **170**, 749, **2021**.
14. SACHS J.D., WARNER A. Natural resource abundance and economic growth. National Bureau of Economic Research Cambridge, Mass., USA. 4, **1995**.
15. ZHOU X., TANG X., ZHANG R. Impact of green finance on economic development and environmental quality: a study based on provincial panel data from China. Environmental Science and Pollution Research. **27**, 19915, **2020**.
16. ZHANG M., LI H., SU B., YANG X. Using a new two-dimensional decoupling model to evaluate the decoupling state of global energy footprint. Sustainable Cities and Society. **63**,102461, **2020**.
17. ZHAO X., LUO D. Driving force of rising renewable energy in China: Environment, regulation and employment. Renewable and Sustainable Energy Reviews. **68**, 48, **2017**.
18. ANTON S.G., NUCU A.E.A. The effect of financial development on renewable energy consumption. A panel data approach. Renewable Energy. **147**, 330, **2020**.
19. USMAN M., KOUSAR R., YASEEN M.R., MAKHDUM M.S.A. An empirical nexus between economic growth, energy utilization, trade policy, and ecological footprint: a continent-wise comparison in upper-middle-income countries. Environmental Science and Pollution Research. **27**, 38995, **2020**.
20. BANK W. Renewable energy consumption (% of total final energy consumption). Sustainable Energy for All database World Bank. Available online: https://data.worldbank.org/indicator/EG.FEC.RNEW.ZS (accessed on 14.09.2023). **2015**.
21. PATHAK L., SHAH K. Renewable energy resources, policies and gaps in BRICS countries and the global impact. Frontiers in Energy. **13**, 506, **2019**.
22. ŚLUSARCZYK B., KOT S. Polish government impact on foreign direct investments. Polish Journal of Management Studies. **6**, 45, **2012**.
23. DANISH, WANG Z. Investigation of the ecological footprint's driving factors: What we learn from the experience of emerging economies. Sustainable Cities and Society. **49**, 101626, **2019**.
24. DREHER A. Does globalization affect growth? Evidence from a new index of globalization. Applied economics. **38**(10), 1091, **2006**.
25. ALOLA A.A., BEKUN F.V., SARKODIE S.A. Dynamic impact of trade policy, economic growth, fertility rate, renewable and non-renewable energy consumption on ecological footprint in Europe. Science of the Total Environment. **685**, 702, **2019**.
26. SACHAN A., SAHU U.K., PRADHAN A.K., THOMAS R. Examining the drivers of renewable energy consumption: Evidence from BRICS nations. Renewable Energy. **202**, 1402, **2023**.