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Examining the Factors Enhancing Green Growth in BRICS Economies: Interplay between Economic Globalization, Renewable Energy Use, and Government Efficiency

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ABSTRACT

Studying economic green growth (EGG) and identifying its drivers have always been crucial for understanding Arabia's sustainable economic development. Given Arabia's extensive economic globalization process, potential impacts on the country's green growth include government effectiveness and inward energy consumption. This study examines the effects of globalization, renewable energy, and institutional quality on green growth across BRICS+ countries from 1996 to 2021. This research mainly empirically explores that economic development, institutional quality, and globalization generally support green growth, while renewable energy offers long-term benefits despite short-term challenges. Non-renewable energy and environmental factors like population growth and forest areas have mixed or context-dependent impacts. Policies aimed at advancing renewable energy and improving energy efficiency have proven highly effective in reducing emissions. However, careful management is necessary to mitigate the environmental impact of free trade and dependence on non-renewable energy sources.

Keywords: Economic Globalization, Renewable Energy, Institutional Quality, Green Growth
JEL Classifications: F02; Q42; O43; Q56

1. INTRODUCTION

The Green Growth narrative did not emerge out of nowhere. It is a continuation of several decades of conceptual attempts, within the international scene, to reconcile prosperity and protection of the environment, with the broad deployment of the concept of 'sustainable development' as a major achievement (Dale et al., 2016; Wanner, 2015; Jacobs, 2013). In the 1960s and 1970s, environmental issues and ecological thinking began to gain momentum in public opinion. A critical discourse on the role of economic growth and industrial development in environmental degradation has emerged and has culminated in 1972 with the Stockholm Conference and the Club of Rome report (Bernstein, 2002). That which can be considered as one of the first waves of the environmental movement, taking a radical debate on the structures of consumption and production of our capitalist societies, has, however, weight loss from the 1980s. It was during this period that the concept of sustainable development emerged as the new buzzword, becoming "the dominant conceptual framework for responses to international environmental problems and capturing the imagination of world opinion" (Bernstein, 2002, p. 3). In addition to its dissemination by international institutions and economic spheres (Neusterer, 2016), it is in particular via the Brundtland Report published in 1987 by the United Nations World Commission on Environment and Development that the term was popularized. Nevertheless, it was in 1992, at the Rio Earth Summit, that the concept of sustainable development was truly institutionalized on an international scale, becoming the principle of international environmental policy, as well as a guiding concept for international environmental policy and environmental and development issues in many countries (Jacobs, 2013).

The spirit behind this new concept was to bring legitimacy to growth and development in a context of environmental protection (Bernstein, 2002), thus defusing the debate between these two objectives, previously presented as profoundly antagonistic (Wanner, 2015). Little by little, the aspects of radical ecological criticisms, which prevailed for a decade, were absorbed into the broader concept of sustainable development, and the idea of a desirable and achievable balance between socio-economic prosperity and the protection of the environment has become the majority (Dale et al., 2016; Bernstein, 2002). Wanner (2015, p. 24) argues that the emergence of the dominant discourse on sustainable development during the 1980s and early 1990s marked a significant turning point. He suggests that this discourse played a role in sustaining capitalist hegemony by countering environmentalist calls for "limits to growth". It is some twenty years after the popularization of sustainable development that the notion of green growth, a term that was little heard before 2008 (Jacobs, 2013), has come to the fore, including through the major economic and development organizations (OECD, 2011; Jacobs, 2013; Bowen and Hepburn, 2014). The OECD have formally committed themselves to promoting growth in their programs and research (OECD, 2011). The United Nations has also led the development and dissemination of Green Growth with the publication of a report of more than 600 pages proposing a trajectory for the implementation of this approach (UNEP, 2011). In addition, two new international bodies, the Global Green Growth Institute (GGI) and the Global Green Growth Institute (GGI), will also be established by the Global Green Growth Institute (GGI). The Green Growth Knowledge Platform has been set up with the aim of assisting countries in the implementation of Green Growth and conducting research around this field of study (Jacobs, 2013).

This approach was also presented as one of the major themes of the Rio+20 Conference in 2012 (Bartelemus, 2013; Hickel and Kallis, 2019). The major international institutions that have participated in the formulation and dissemination of the concept of Green Growth nevertheless explain that it is not a substitute for 'sustainable development' but rather a means to achieve it (Jacobs, 2013; OECD, 2011; UNEP, 2011). Several G20 summits (Jacobs, 2013) and many governments around the world (Vasquez-Brust et al., 2014) have also approached over the past decade. More recently, the Green Deal for Europe (or European Green Deal), presented in 2019 by the Commission, carries with it many aspects specific to Green Growth (Ossewaarde and Ossewaarde-Lowtoo, 2020; Pianta & Lucchese, 2020). Several academics nevertheless try to explain the reasons for the adoption and dissemination of this new term and the political discourse that surrounds it (Brand, 2012; Jacobs, 2013; Wanner, 2014). First, the implicit recognition of the failure of sustainable development is put forward (Brand, 2012; Jacobs, 2013). Indeed, it is clear that more than 20 years of institutionalization and popularization of this concept, which nevertheless aimed at a better balance between social development and environmental protection, have not prevented environmental degradation, ever-increasing utilization, ever-increasing use of natural resources, and increasing opportunities for climate change that are ever more alarming (Steffen et al., 2015).

The notion of green growth has therefore mainly been conceptualized and popularized by three major institutions: The World Bank, the OECD, and the United Nations (Ossewaarde and Ossewaarde-Lowtoo, 2020; Jacobs, 2013), in the context of the Rio+20 Conference 2012. The OECD's Towards Green Growth plan defines "green growth" as fostering economic development while ensuring that natural resources continue to sustain the environmental services vital to human well-being. Achieving this requires driving innovation and investment to support sustainable, long-term growth while unlocking new business opportunities (OECD, 2011, p. 4). This definition has been adopted by several academics (Buch-Hansen and Cartensen, 2021; Hickel and Kallis, 2019; Jacobs, 2013) and provides a first overview of the key principles of Green Growth. Nevertheless, there is no precise consensus or common definition around this narrative (Buch-Hansen and Cartensen, 2021). What unites the promoters of the Green Growth discourse is the idea that it is economic prosperity and environmental protection (Buch-Hansen and Cartensen, 2021; Hickel & Kallis, 2019; Bowen and Hepburn, 2014). This approach, "characterized by operating within the existing capitalist systemic logic" (Buch-Hansen and Cartensen, 2021), therefore assumes that environmental sustainability can be achieved without calling into question the current economic and societal structures, for example, in terms of questioning the current consumerism or 'Western lifestyle' standards (Sandberg et al., 2019; Ossewaarde and Ossewaarde-Lowtoo, 2020). This aspect thus obscures the political character of the question of responsibilities for environmental degradation (Ossewaarde and Ossewaarde-Lowtoo, 2020). At On the contrary, Green Growth is based on the theory of negative externalities widely deployed by the 'environmental economists' from the neo-classical school of thought (Loiseau et al., 2016; Sandberg et al., 2019). This postulates that environmental degradation is an external cost to the market and that if these costs were internalized (e.g., in prices), the market would solve the adverse effects on the environment (Loiseau et al., 2016; Sandberg et al., 2019).

The fundamental element behind environmental degradation is greenhouse gas emissions, particularly CO_2 emissions (Farooq et al., 2021; Anwar et al., 2022a). The solution to this problem is to attain sustainable economic growth, which is known as "green growth" (GGDP). Henceforward, Green GDP should be considered an essential measure while arranging sustainable development policies. Current literature has examined the impact of various determinants of green growth such us human development and green energy (Wang et al., 2023), FDI (Lin and Zhou, 2022), natural resources (Cheng et al., 2020), ICT (Wang et al., 2022), environmental policy (Xu et al., 2022), R&D expenditure (Zhou and al, 2022), among others. Combustible and wastes renewable energy have considered as extremely pollution-intensive energy sources. For this reason, Renewable energy consumption could increase CO_2 emissions. However, globalization and corruption control could be proved essential drivers of green growth. Moreover, to reach green economic growth, properly operational institutions are needed (Ahmed et al., 2023; Haldar and Sethi, 2021; Karim et al., 2022). Institutional indicators particularly corruption, political stability, government regulation, the rule of law, and government efficacy are supposed to have a significant effect on environmental policies and devices to reduce carbon emissions (Qamruzzaman & Karim, 2024; Abid et al., 2022; Yeboah et al., 2024; Karim et al., 2022) and improve green economic growth Jiang et al. (2023). Then, few empirical studies are in the favor of globalization to develop green growth whereas few are against the globalization in prospect of green growth. Empirically, it is been proved that globalization is source to raise the green growth (Zafar et al., 2019). On the contrary side few studies indicate that globalization is destructive for the green growth of the country as it damages climate condition and influence greenhouse gases as well.

The map highlights the BRICS countries, divided into two groups: Old BRICS members (in blue) and New BRICS members (in green) (Figure 1). The founding members include Brazil, Russia, India, China, and South Africa, which are some of the largest emerging economies globally. Together, these nations represent over 40% of the world's population and account for nearly 25% of global GDP. Key demographic data shows that China and India are the world's two most populous countries, with over 1.4 billion people each, while Brazil has approximately 215 million people, Russia around 144 million, and South Africa about 60 million. The new BRICS members—Saudi Arabia, Iran, United Arab Emirates (UAE), Egypt, Ethiopia, and Argentina—further expand the bloc's demographic and economic reach. For example, Saudi Arabia has a population of around 36 million and is a major energy powerhouse, while Egypt and Ethiopia add over 110 million and 120 million people, respectively, bolstering Africa's representation. Iran and the UAE contribute significant economic influence in the Middle East, with populations of around 89 million and 10 million, respectively, while Argentina adds 45 million people from South America. Collectively, the expansion of BRICS reflects its growing geopolitical and economic importance, with the bloc now encompassing regions that together hold over 50% of the world's population, signifying a major shift in global influence towards the Global South.

The graph, in Figure 2, shows renewable energy consumption from 1995 to 2016 for various countries, highlighting stark differences in trends. China experienced a dramatic surge in renewable energy usage, especially after 2005, reaching over 4,000 TWh by 2016, far outpacing all other nations. Brazil followed as the second-highest consumer with steady growth throughout the period, reflecting its reliance on sources like hydropower. The Russian Federation saw relatively flat growth, indicating a lesser focus on renewables, while India exhibited gradual increases, particularly post-2005, but remained far below China and Brazil. Other countries, such as South Africa, Saudi Arabia, Egypt, Iran, Argentina, and Ethiopia, displayed minimal renewable energy consumption and limited growth, suggesting continued dependence on traditional energy sources. Overall, the graph highlights a global shift towards renewables, driven significantly by China, with notable progress in Brazil and India, while most other countries lagged behind.

2. LITERATURE REVIEW

Tawiah et al. (2021) uses data on 123 developed and developing countries to examine factors that influence green growth. The empirical results present that economic development positively influences green growth. However, trade openness is unfavorable to green growth. Regarding energy-related factors, the authors find that energy consumption affects negatively green growth, but renewable energy consumption significantly improves green growth. In further analysis, they find that the impact of these factors diverges between developed and developing countries. The result implies that countries at a different development level will require different strategies in achieving the Sustainable Development Goals in 2030. The results are robust to alternative identification strategies such as the System Generalised Method of Movement, which accounts for potential endogeneity. The impacts of economic globalization on environmental degradation are explored in the E7 economies in the presence of some control variables including economic growth, natural resources, urbanization, and human capital between 1990 and 2016 in a carbon-income environment. Onifade et al. (2021) applies a panel regression analysis using the Augmented Mean Group (AMG) estimator of Eberhardt and Bond and Eberhardt and Teal method for the long run estimation. The study also uses the fully modified ordinary least square (FMOLS) and dynamic ordinal least square (DOLS) to evaluate the long-run relationship between the variables using both CO_2 emission and ecological footprint (ECF) as dependent variables in distinct models. Key important results from the study stand out. Firstly, the study reveals that globalization is negatively correlated with CO_2 emission and the ecological footprint of the E7 economies. This finding depicts the significance of economic integration among countries as a significant tool for cushioning environmental degradation. Secondly, the study demonstrates that natural resources, urbanization, and economic growth increase pollution in both models. Thirdly, human capital reduces environmental pollution in the E7 and its pollution abating impacts also cushion environmental degradation from growing urbanization as the interaction between both variables significantly abates pollution in the E7 bloc. Overall, the study suggests some policy ideas including the establishment of clean discovery regulation and the implementation of conservation initiatives, enhanced human capital investment initiatives, and carefully designed economic integration policies to attract foreign investors with innovative technologies to maximize environmental pros of the era of globalization.

Seyi Saint et al. (2019) apply an autoregressive distributed lag (ARDL) methodology to a panel data of 28 European Union (EU-28) countries over the period 1995–2015. The results confirm the existence of positive and significant long-run nexus among environmental sustainability, renewable energy consumption and economic growth in the EU-28 countries. Moreover, empirical results show that real gross fixed capital formation, carbon emissions and other environmental factors are principal determinants of long-run growth in the EU. Using Dumitrescu and Hurlin (2012) Granger non-causality in heterogeneous panel, results illustrate long-run bidirectional causal relationships among renewable energy consumption, economic growth and other growth determinants. Based on these results, we conclude that the exploitation of renewable energy sources in the EU-28 countries is a reliable pathway toward environmental pollution mitigation. Subsequently, achieving sustainable development goals (SDGs) by the year 2030 through renewable energy consumption and carbon emission mitigation is very much achievable in the EU-28 countries, and should also be adopted by all countries as an effective global policy. Ghulam and Rabia (2015) debate the important determinants requires to develop green patents, which finally reinforce green growth. The theoretical framework inspected four elements, the enforcement of intellectual property rights (IPRs), research and development (R&D) expenditures, market size and environmental taxations. They empirically exam the green patent data to test the interrelationship of green patents representing the green innovations and IPR, R&D expenditures, market size and environmental taxations. This study used also the Pooled Least Square estimation techniques such as Fixed Effect Model (FEM) and random effect model (REM) for both balance period of 1995–2010 and unbalanced period from 1995–2010. They interpreted the balance period results depicting the enforcement of IPRs has negative and significant impact on green patents while the R&D expenditures, market size and environmental taxations has positive and significant impact on the green patents e.g. development of green innovations. They consider that the enforcement of explanatory variables will ultimately attain green growth.

Li et al. (2022) use system generalized method of moments estimator for exploring the impacts of green energy and green technological on green growth. They also examine the moderating and mediating roles of green technological innovation, heterogeneity, and asymmetry in 3G nexus. The empirics results show that technological innovation is positively associated with green growth and green technological innovation can increase the positive influence of green energy on growth and further promote sustainable economic development. Therefore, green technological innovation is a positive mediator in the impact of green energy on growth. Finally, the impact of green energy is heterogeneous and asymmetric, while the influence of green technological innovation is consistent. Arzova et al. (2023) analyze the Green Growth from a financial economy perspective and determine the contribution of financial development and innovation to Green Growth in Brazil, Russian Federation, India, China and South Africa and Türkiye (BRICS-T). BRICS-T countries significantly affect the world population, international politics, energy resources and economy. Furthermore, BRICS-T countries are one of the principal countries in the world with their sustainability efforts. The authors apply panel data analysis from 2001 to 2019. Green Growth is economic growth free from environmental depletion in the model. National income, personnel expenditure and foreign direct investments are macroeconomic variables. These variables measure economic development and promote economic and social progress, which is essential for Green Growth. Capital accumulation, digital transformation and innovation are essential tools in Green Growth transformation (Gaglio et al., 2022). Therefore, financial development and patent applications represent the moderating variables. The authors estimate the fixed effect model with Parks-Kmenta robust. Empirical results show that national income growth and foreign direct investments positively affect Green Growth. Personnel expenditure negatively affects Green Growth. On the contrary, financial development and patent growth have little moderating role. Odugbesan et al. (2021) attempt to model the determinant factors of green growth in the MENAT countries using data from 1990 to 2019 and employe the Westerlund and Edgerton (2008) panel cointegration test to examine the cointegration among the variables of interest, and employe DCCE-MG technique to establish the significance of the determinant factors, while FMOLS and DOLS were utilized for robustness check. The result from the panel cointegration test exposed an existence of cointegration relationship between the variables in cases of "cross-sectional dependency" and structural breaks, which suggests that the variables move together in the long-run. Moreover, the findings from DCCE-MG estimates showed that foreign direct investment, economic growth, renewable energy and institutional quality drives sustainable green growth in the MENAT countries, while population was found to exert negative impact on sustainable green growth.

Teklie and Yağmur (2024) study the impact of green innovation, renewable energy consumption, and institutional quality on green growth in African countries, controlling for GDP per capita, trade openness, foreign direct investment (FDI), population, and natural resource rent by using pooled mean group (PMG), mean group (MG), and dynamic fixed effects (DFE) models with panel data for 49 African countries from 2000 to 2021. The results show that green innovation, renewable energy consumption, institutional quality, GDP per capita, trade openness, and population growth have positive long-run effects on green growth. In contrast, FDI and natural resource depletion have contrary effects. In the short run, only institutional quality and GDP per capita positively affect green growth, while natural resource rent has a negative impact. Considering these findings, this study recommends that policymakers in Africa promote green innovation and adopt energy-efficient technologies, increase the use of renewable energy resources, and improve institutional quality to achieve green growth. Awan et al. (2022) create a Green Growth Index and empirically test its long-run and short-run determinants for the time series data from 1990 to 2021 in the case of Bangladesh, India and Pakistan. A set of nineteen indicators covering three dimensions, including resource productivity, environmental quality and economic and social aspects, is used to develop the Green Growth index through the principal component methodology. Given the mixed order of integration, Autoregressive Distributed Lag (ARDL) method is used to check the co-integration relationship of variables. The results of this study illustrate that in the case of Bangladesh, there are three significant determinants in which urbanization and forest area are positively associated with Green Growth and trade openness negatively. Urbanization, trade openness, law and order have significant and positive relationships with Green Growth, while socio-economic conditions have significant but negative correlations in Pakistan. Therefore, this study suggests that policies related to urbanization, trade openness, forest area, law and order and socio-economic conditions stimulate Green Growth.

From 1985 to 2018 in thirty-six (OECD) countries Cao et al (2022) studied the impact of the financial development, stock market, globalization, institutional quality, economic growth, electricity and renewable energy consumption on carbon dioxide emission. Cointegrations exist in the used variables based on the examined findings of the Kao, Westerlund, and Pedroni cointegration. Findings of the pooled mean group (PMG) indicate that renewable energy consumption, globalization, and institutional quality reduce the carbon dioxide emission that improve the environment. Financial development, stock market, electricity consumption, and economic growth increase the carbon dioxide emission in OECD countries both in the long and in the short run. Important policy implications are suggested for OECD countries for reducing carbon dioxide emissions. Using dynamic ARDL simulations model by Jordan and Philips (2018), Islam et al. (2021) attempt to study the effect of globalization, foreign direct investment, economic growth, trade, innovation, urbanization, and energy consumption on CO_2 emissions in the presence of institutional quality in Bangladesh over the period 1972–2016. The results show that globalization, foreign direct investment, and innovation have a negative effect on CO_2 emissions in improving environmental quality while economic growth, trade, energy consumption, and urbanization positively impact CO_2 emissions and hence stimulate environmental degradation both in the long and short run. Institutional quality affects CO_2 emissions positively and thereby destroy the quality of the environment in both the long and short run. Wang and al., (2023) propose the affecting mechanism of institutional quality in the relationship between natural resource abundance and green economic growth. They use Panel threshold models to investigate the role of institutional quality in preventing resource curse and conduct heterogeneous analysis of different income levels. The results suggest that the resource curse on green economic growth could be eliminated as the institutional quality went above the threshold value for BRI countries. For high-income countries, the promotion effect of natural resource abundance increased significantly when institutional quality was above the threshold value, while for low- and middle-income countries, natural resource curses did significantly exist and turned to be a blessing only when institutional quality was above certain threshold. Therefore, improving institutional quality would be an active way in green economic growth of BRI countries.

Based on the subject of present interest, the review of the above-cited studies reveals several gaps. First, A minority of studies have studied the impact of globalization on green growth specially almost all have ignored the impact of financial globalization on green economic. Second, institutional quality is a pronounced and complex concept, and its vast effects may not be well investigated by using single or inadequate alternatives. For instance, different studies used different alternatives, such as corruption, democracy, and government effectiveness. These indicators may not correspond to the comprehensive concept of institutional quality. Moreover, after a thorough review of the available literature, many studies observed that the empirical evidence provides contradictory arguments regarding the nexus of green growth and renewable energy consumption (Jiang et al. (2023); Hwang & Díez (2024)), which could lead to destructive policies. Also, the literature is observed covering limited time periods along with the traditional econometric approaches to explore the link between the supposed variables. Therefore, this study tried to fill this gap by using advanced and appropriate econometric approaches for achieving the evidence more comprehensively. Based on the literature, the following hypotheses are formulated in the current study:

- Hypothesis 1: Globalization plays a significant role in sustainable growth in BRICS+ Countries.
- Hypothesis 2: Institutional Quality plays a significant role in leading green growth and verifies specific policy implications in BRICS+ Countries.
- Hypothesis 3: Renewable energy resources are associated with green growth plays in BRICS+ Countries.
- Hypothesis 4: Natural resource utilization plays a significant role in sustainable economic growth in BRICS+ Countries.

The Research Gap interested in this work and reviewed of the above literature reveals that the role of the selected regressors in economic green growth or sustainable economic growth in the context of different countries or group of countries, but no definite conclusion about their contribution to sustainable growth have been reached. Therefore, further analysis of the matter is required. Moreover, to the author's best understanding, no previous study selected BRICS group for the estimation of this objective. Therefore, the current study tries to fill this gap in literature by examining the role of these factors in sustainable growth in the selected BRICS countries.

3. DATA, ESTIMATIONS AND ANALYSIS

The main objective of this paper is to examine the effects of economic globalization, renewable energy, and institutional quality on economic green growth for the large group of BRICS economies during the period 1996-2022. The data source is World Bank, KOF Swiss Economic Institute, The Worldwide Governance Indicators. The research was conducted at an individual level, by taking into consideration the time period 1996-2022. Income (GDP) per capita has been used to measure economic growth. For the green growth, one proxy has been used, which includes growth as measured by Production-based CO_2 emissions on tone. We use a battery of control variables often mentioned in the literature relating to the determinants of growth. This framework ensures a systematic approach to testing the developed research hypotheses and achieving the primary objectives of the study. Similar methodological approach has been largely used in prior literature.

3.1. Data Source and Model Specification

Based on the literature review and the established hypothesis, we aim to investigate and assess the determinants of green growth and the effects of control variables in the context of BRICS countries, using cointegration relationships and panel estimation approaches. To achieve this objective, we use panel data and adopt an aggregate linear model, where economic green growth is the endogenous variable explained by real GDP per capita, the globalization index, institutional quality, energy consumption, and the natural resources index (Table 1).

3.1.1. Variables and sources data

This study employs factors that clarify economic green growth, including governance indicators such as economic growth, globalization, energy consumption, institutional quality, and land usage. The data are sourced from reputable institutions, including the OECD, World Bank, KOF Swiss Economic Institute, and Worldwide Governance Indicators, ensuring reliability and

Table 1: Description and sources of variables

Variable code	Definition	Measurement	Source
EGG	Economic Green growth	Environmental and resources productivity	OECD Statistics
GDPC	Economic growth	Real GDP per capita, linearized by logarithm	World Bank; World Development Indicators
ECGI	Economic globalization index		KOF Swiss Economic Institute
FIGI	Economic globalization index		KOF Swiss Economic Institute
REC	Renewable Energy consumption	Renewable energy consumption is the share of renewable energy in total final energy consumption	World Development Indicators
NREC	Non-Renewable Energy consumption	Non-Renewable energy consumption is the share of Non-renewable energy in total final energy consumption	
GOEE	Government Effectiveness: Estimate the Institutional Quality	Estimate of governance (ranges from approximately−2.5 (weak) to 2.5 (strong) governance performance)	Worldwide Governance Indicators
CC	Control of Corruption:	Estimate the Institutional Quality	Worldwide Governance Indicators
POPG	Population growth	Population growth (annual %)	World Development Indicators
FTA	Forest area land	Forest area (% of land area)	World Development Indicators

accuracy for analysis. Table 1 provides a detailed description of the variables used in this study, including their definitions, measurement methods, and data sources.

3.1.2. Specification model

We test the model defined in the following equation: the effect of economic globalization, energy consumption, and institutional quality on green growth.

$$EGG_{it} = \beta_0 + \beta_1 GI_{it} + \beta_2 GI_{it} + \beta_3 IQ + \beta_3 ClV + \varepsilon_{it}$$

Where, EGG_{it} is real GDP per capita expressed in logarithm and X represents a set of explanatory variables other than the lagged (initial) value of real GDP per capita. µi represents the country-specific effect, νt is the time-specific effect and ε the error term. The indices i and t denote the countries (i = 1, 2… N) and the periods (t = 1, 2… T) respectively. This equation can be rewritten as follows:

3.1.2.1. CIPS panel unit root test

The CIPS (Cross-Sectionally Augmented IPS) panel unit root test is an advanced econometric test designed to detect unit roots in panel data. It extends the IPS (Im, Pesaran, and Shin) test by accounting for cross-sectional dependence, which is a common issue in panel datasets where residuals are correlated across cross-sections. The CIPS statistic is calculated as the average of individual cross-sectionally augmented Dickey-Fuller (CADF) test statistics. The CADF test incorporates cross-sectional averages to remove the impact of common factors. It is conducted as follow:

The regression of every variable for each cross-sectional unit i:

$$\Delta_{yi,t} = \alpha_i + \beta y_{i,t-1} + \gamma_i \bar{y}_{t-1} + \sum_{i=1}^{p} \delta_{ij} \Delta y_{i,t-j} + \sum_{i=1}^{p} \varnothing_j \Delta_{\bar{y}_{t-j}} + \in_{i,t}$$

Where:

$\bar{y}_{t-1}$: Cross-sectional of y_{t-1}

$\Delta_{\bar{y}_{t-j}}$ Cross-sectional average of the lagged first differences.

Average the CADF statistics across all cross-sections:

Table 2: Panel unit root test with cross-sectional dependence: Pesaran et al. (2004) - CIPS

Variables	CIPS			
	I (0)		I (1)	
	t-stat	P-value	t-stat	P-value
LOG (GGE)	−2.219*	<0.10	--	--
LOG (GDPPC)	−2.396**	<0.05	--	--
ECGI	−2.663***	<0.01	--	--
FIGI	−2.271*	<0.10	--	--
GOEE	−1.285	≥0.10	−5.296***	<0.01
CC	−1.142	>=0.10	−3.441***	<0.01
REC	−2.046***	<0.01	--	--
NREC	−1.962	≥0.10	−2.857***	<0.01
POPG	−3.203***	<0.01	--	--
FTA	−2.255	≥0.10	−1.628*	<0.10

Source: Authors established

$$CIPS = \frac{1}{N}\sum_{i=1}^{N} CADF_i$$

About the Critical Values and Decision of CIPS approach, the test statistic is compared against tabulated critical values provided by Pesaran (2007) for different panel sizes and lag structures.

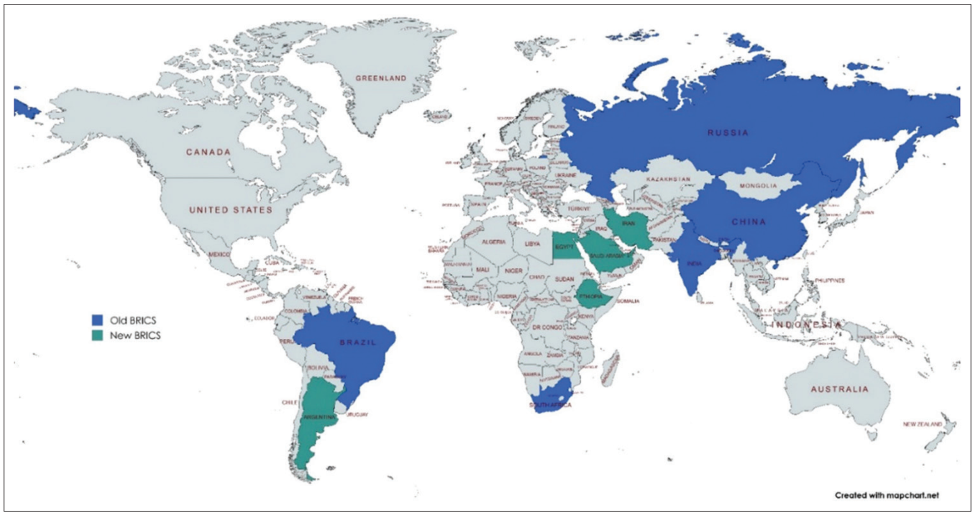
Table 2 summarizes the results of the Panel Unit Root Test with Cross-Sectional Dependence using the Pesaran et al. (2004) CIPS test, which determines whether the variables are stationary at their level (I(0)) or become stationary after first differencing (I(1)).

The table 2 presents the results of the Pesaran et al. (2004) CIPS panel unit root test to assess the stationarity of variables. Variables such as LOG(GGE), LOG(GDPPC), ECGI, FIGI, REC, and POPG are stationary at their levels (I(0)), requiring no differencing. In contrast, variables like GOEE, CC, NREC, and FTA are non-stationary at their levels but become stationary after first differencing (I(1)), indicating they exhibit unit roots initially but stabilize after differencing. This distinction ensures proper treatment of variables in econometric modeling.

3.2. Estimated Models

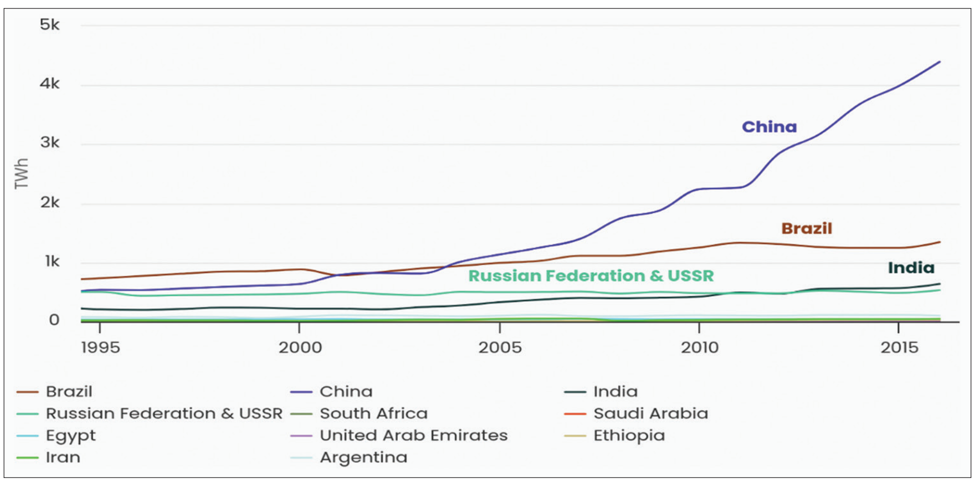
This section outlines the econometric models used to analyze the

Figure 1: Geographic maps of BRICS+ economies



Source: Authors established using Mapchart.net

Figure 2: Renewable energy consumption 1995–2016



Source: Authors established using Mapchart.net

determinants of Economic Green Growth (EGG). The models incorporate key explanatory variables such as GDP per capita, globalization, institutional quality, energy, and other control variables to capture the factors influencing green growth dynamics. The models are specified as follows:

- Model (M1):

$$EGG_{it} = \beta_0 + \beta_1\ GDPPC_{it} + \beta_2\ Globalisation_{it} + \beta_3\ Control\ variables + \varepsilon_{it}$$

This model examines the impact of GDP per capita and globalization on economic green growth, controlling additional relevant factors.

- Model (M2):

$$EGG_{it} = \beta_0 + \beta_1\ GDPPC_{it} + \beta_2\ Institutional\ Quality_{it} + \beta_3\ Control\ variables + \varepsilon_{it}$$

Here, the focus shifts to institutional quality as a key determinant of green growth alongside GDP per capita.

- Model (M3):

$$EGG_{it} = \beta_0 + \beta_1\ GDPPC_{it} + \beta_2\ Energy_{it} + \beta_3\ Control\ variables + \varepsilon_{it}$$

This model introduces energy usage as an explanatory factor, exploring its relationship with economic green growth.

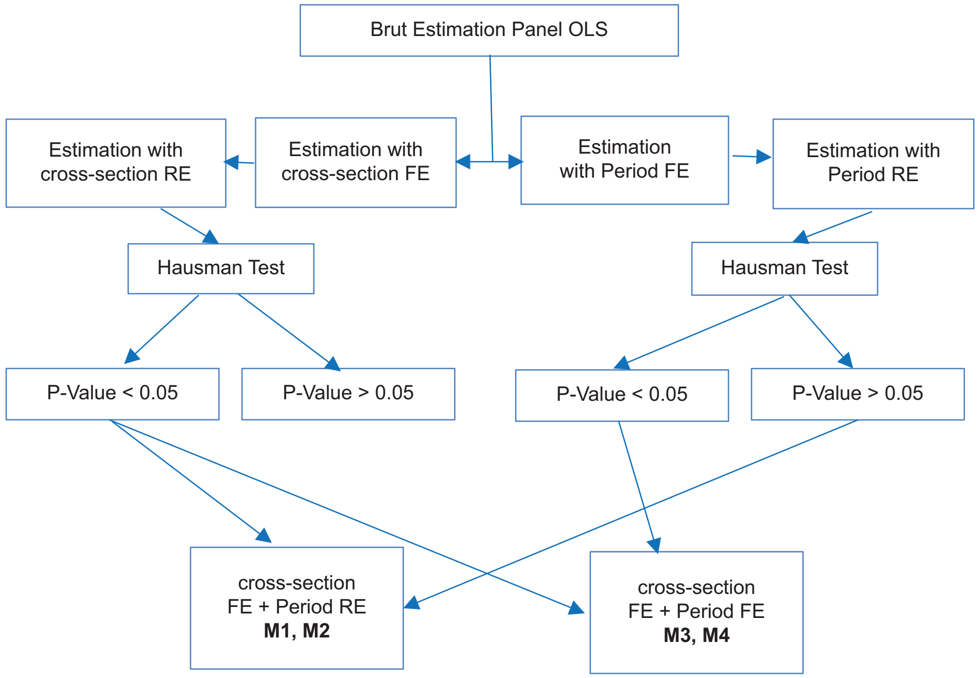
- Model (M4):

$$EGG_{it} = \beta_0 + \beta_1\ GDPPC_{it} + \beta_2\ GI_{it} + \beta_3\ IQ + \beta_4\ EC_{it} + \beta_5\ Control\ variables + \varepsilon_{it}$$

In this extended model, multiple factors are considered, including GDP per capita, green innovation (GI), institutional quality (IQ), and energy consumption (EC), providing a comprehensive framework for understanding the drivers of green growth.

Notes: EGG_{it} represents the indicator of Economic Green Growth. And Mj corresponds to the different models specified above (M1, M2, M3 and M4), with i and t representing country and time dimensions, respectively. These models are designed to capture the multidimensional aspects of green growth by incorporating economic, institutional, and environmental factors,

Figure 3: Estimations process of models



Source: Authors established

offering insights into the pathways for achieving sustainable development.

4. FINDINGS AND DISCUSSION

The estimations of four models above, was implemented with identification of cross-section and period fixed and random effects. Attending the last results of findings pass thought a prossess of identification present in the Figure 3.

Figure 3 outlines the process of estimating panel data models, beginning with the Brut Estimation Panel OLS method and progressing through several steps based on statistical criteria. The process involves four initial estimations: Cross-section RE (Random Effects), Cross-section FE (Fixed Effects), Period RE (Random Effects), and Period FE (Fixed Effects). To determine the most suitable model, the Hausman Test is applied to compare the fixed and random effects models for both cross-section and period dimensions. The decision is based on the p-value: if it is less than 0.05, the fixed effects model is selected, indicating that the fixed effects better capture the data's variability; otherwise, the random effects model is preferred. Finally, the chosen models are combined, resulting in either Cross-section FE + Period RE (Models M1 and M2) or Cross-section FE + Period FE (Models M3 and M4), depending on the statistical significance and compatibility of the effects. Thus, table 4 summarizes the final results after using the necessary methods to highlight the specification effects.

The Table 3 summarizes the results of estimations for the dependent variable Green Growth Economy (GGE) using different methods (M1–M5). Every model represents a results of specification analysis of cross-section and period effects using Hausman test as indicated in the Table 3.

- Economic Development (GDPPC) is positive and significant in M1, M2, M3, and M4, with high coefficients (e.g., 0.8063* in M1 and 0.8378* in M2, both significant at the 1% level), suggesting that higher per capita GDP is strongly associated with green growth and affirming the importance of economic development; however, in M5, the relationship turns negative (−1.1702), indicating potential non-linear or complex dynamics in how GDP influences green growth under more robust specifications. Economic Development (GDPPC) plays a crucial role in promoting green growth across most models, but its effect can vary based on the estimation method.
- Government Effectiveness (GOEE) is positive and significant in M2, M4, and M5, with coefficients such as 0.1127 in M2 and 0.5239* in M5, indicating that better government effectiveness facilitates green growth. Similarly, Control of Corruption (CC) is positive and significant in M2 and M4, showing that reducing corruption positively impacts green growth; however, it becomes negative in M5 (-0.1853*), suggesting a more nuanced role of corruption control under robust model specifications. These results confirmed the findings of the work done by Jiang et al. (2023). Institutional quality and renewable energy consumption increase green growth. Briefly, Institutional Quality (Government Effectiveness and Control of Corruption) generally supports green growth, though its impact can differ based on the context.
- Economic Globalization (ECGI) is positive and significant in M1 (0.0103*), indicating a beneficial role of economic globalization in green growth, but it becomes insignificant in M3 and M4, showing inconsistency across methods; however, it is positive again in M5 with a stronger effect (0.0303), reaffirming its importance in robust estimations. In contrast, Financial Globalization (FIGI) is insignificant across all models, suggesting that it may not have a direct impact on green growth. In summary, we say that, economic globalization

Table 3: Summary of estimations results

Estimation Methods	Dependent variable: Green growth economy (GGE)				
	M1: PEGLS (Cross-section FE + Period RE)	M2: PEGLS (Cross-section FE + Period RE)	M3: PLS (Cross-section FE + Period RE)	M4: PLS (Cross-section FE + Period RE)	M4': RLS Robust Least Squares
Exogenous variables	Globalization	Institutional Quality	Energy	Overall	Overall
Economic Development (GDPPC)	0.8063*** (0.000)	0.8378*** (0.0000)	0.2195*** (0.0000)	0.1156** (0.0187)	−1.1702 (0.0000)
Economic globalisation index (ECGI)	0.0103*** (0.0043)			−0.0012 (0.5601)	0.0303 (0.0000)
Financial globalisation index (FIGI)	0.0027 (0.2828)				
Government Effectiveness (GOEE)		0.1127** (0.0233)		0.1231** (0.0131)	0.5239*** (0.0000)
Control of corruption (CC)		0.1740*** (0.0003)		0.2157*** (0.0000)	−0.1853*** (0.0000)
Renewable energy consumption (REC)			−0.0321*** (0.0000)	−0.0343*** (0.0000)	0.0580*** (0.0000)
Non-Renewable Energy consumption (NREC)			−0.0154*** (0.0044)	−0.0034 (0.5149)	0.1341*** (0.0000)
Population growth (POPG)	−0.0337*** (0.0000)	−0.0324*** (0.0003)	−0.0021*** (0.7614)	−0.0032 (0.6164)	−0.1192*** (0.0000)
Forest area (FTA)	−0.0378*** (0.0000)	−0.0427*** (0.0000)	−0.0114*** (0.2081)	−0.0220*** (0.0080)	0.0498*** (0.0000)
C	−1.7592*** (0.0000)	−1.2851*** (0.0000)	5.8102*** (0.0000)	6.238*** 0.0000	2.959*** (0.0000)
R-squared	0.98	0.99	0.99	0.99	0.69
F-statistic Prob (F-statistic)	1455.43 (0.0000)	1387.85 (0.0000)	1121.45 (0.0000)	1327.02 (0.0000)	
Hausman Test (cros-section effects)	23.844(1) (0.0002)	13.255 (0.0211)	113.873 (0.0000)	99.845 (0.0000)	
Hausman Test (period effects)	5.922(1) (0.3139)	4.151 (0.5279)	135.391 (0.0000)	205.567 (0.0000)	
Observations	297	297	297	297	297
Cross-section (countries)	11	11	11	11	11

PEGLS: Panel EGLS: PLS: Panel least squares, PRLS: Panel Robust Least Squares, FE: RE: Respectively, Fixed effects and random effects.
(1)Chi-Sq. Statistic (Prob.)

(ECGI) contributes positively, especially under robust estimations, while financial globalization is less impactful.

- Renewable Energy Consumption (REC) is negative and significant in M3 and M4, with coefficients such as −0.0321* and −0.0343* suggesting that higher reliance on renewable energy may negatively impact green growth. This result is contrary to the present work of Hwang & Díez (2024), which takes samples in Latin America. However, our findings here can be explained as being short-term, potentially due to transition costs; however, it becomes positive and significant in M5 (0.0580*), reflecting long-term benefits or robust positive effects. Similarly, Non-Renewable Energy Consumption (NREC) is negative and significant in M3, indicating that reliance on non-renewable energy hinders green growth, but turns positive in M5 (0.1341*), implying that under robust conditions, non-renewables may still contribute to certain aspects of economic growth. Thus we can say that, renewable energy shows long-term benefits for green growth but may involve short-term costs and non-renewable energy has mixed effects depending on the estimation method.
- Environmental factors show varying impacts on green growth. Population Growth (POPG) is negative and significant in most models (M1, M2, M3), with coefficients such as −0.0337* in M1, suggesting that higher population growth poses a challenge to green growth. Forest Area (FTA) is negative in M1, M2, and M4, indicating that forest depletion harms green growth, but it becomes positive in M5 (0.0498*), reflecting the potential positive effects of forest area preservation under robust methods.

5. CONCLUSION AND POLICY IMPLICATIONS

Understanding economic green growth (EGG) and its driving factors has been essential for analyzing Arabia's path toward sustainable economic development. With Arabia's deep integration into the global economy, factors such as government effectiveness and domestic energy consumption significantly influence its green growth trajectory. This study explores the impacts of globalization, energy consumption, and institutional quality on green growth in 10 selected countries from North Africa and the GCC region between 1996 and 2021.

The literature review explores the determinants of green growth across various contexts, highlighting key drivers such as globalization, institutional quality, renewable energy consumption, economic development, and natural resource utilization. Studies reveal that economic development positively influences green growth, while renewable energy enhances environmental sustainability, though its effects can vary across development levels and regions. Globalization, particularly economic globalization, plays a significant role in mitigating environmental degradation, though the impact of financial globalization remains underexplored. Institutional quality emerges as a critical factor, with components like governance, corruption control, and democracy influencing green growth outcomes. Contradictory findings regarding the nexus between renewable energy and green growth, along with limited time frames and traditional econometric approaches, underscore gaps in the literature. Furthermore, studies seldom analyze comprehensive institutional quality or focus on financial globalization, leaving critical aspects unaddressed. This study aims to fill these gaps by using advanced econometric methods to examine the role of globalization, institutional quality, renewable energy, and natural resource utilization in sustainable growth within BRI countries, offering novel insights and policy implications for achieving green economic growth.

Findings highlight that, economic development, institutional quality, and globalization generally support green growth, while renewable energy offers long-term benefits despite short-term challenges. Non-renewable energy and environmental factors like population growth and forest area have mixed or context-dependent impacts.

Policies promoting renewable energy and energy efficiency appear to have significant emission-reducing effects. Free trade and reliance on non-renewable energy may require careful management to minimize their impact on emissions.

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