

# Macroeconomic and financial determinants of green growth: an empirical investigation on BRICS-T countries

Sabri Burak Arzova  
*Marmara University, Istanbul, Turkey, and*  
Bertaç Şakir Şahin  
*Yıldız Technical University, Istanbul, Turkey*

Financial  
determinants  
of green  
growth

Received 12 July 2023  
Revised 4 September 2023  
7 October 2023  
Accepted 8 October 2023

## Abstract

**Purpose** – The purposes of this study are to contribute to the limited green growth (GG) literature in emerging markets, to analyze GG from a financial economy perspective and to determine the contribution of financial development and innovation to GG in Brazil, Russian Federation, India, China and South Africa and Türkiye (BRICS-T). BRICS-T countries significantly impact the world population, international politics, energy resources and economy. In addition, BRICS-T countries are one of the leading countries in the world with their sustainability efforts. Investigating the GG model in these countries may contribute to structuring emerging economies around the principles of GG and advancing global green transformation efforts.

**Design/methodology/approach** – The authors applied panel data analysis from 2001 to 2019. GG 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 GG. Capital accumulation and innovation are essential tools in GG transformation. Therefore, financial development and patent applications represent the moderating variables. The authors estimate the fixed effect model with Parks-Kmenta robust.

**Findings** – Empirical results show that national income growth and foreign direct investments positively affect GG. Personnel expenditure negatively affects GG. On the contrary, financial development and patent growth have little moderating role.

**Originality/value** – This study contributes to the literature on creating a GG model in emerging countries. The study is original in its model and sample.

**Keywords** Green growth, Sustainability, Economic determination of green growth, Financial development

**Paper type** Research paper

## 1. Introduction

Since the Industrial Revolution, humanity has made significant progress in economic development. Policymakers and researchers discuss how economic growth affects sustainability (Saufi *et al.*, 2016). The Intergovernmental Panel on Climate Change (IPCC) and the United Nations, which research sustainability, argue that economic activities are the main drivers of environmental degradation (Intergovernmental Panel on Climate Change, 2021; United Nations, 2022). Additionally, some studies empirically demonstrate the impact of human activities on environmental degradation (Nasir *et al.*, 2021; Baloch *et al.*, 2019a).

Economic growth affects environmental degradation through the misuse of natural resources production and consumption activities, natural resource use, transportation and energy consumption (Sadorsky, 2009). For this reason, international organizations and researchers have reconsidered economic activities from a sustainability perspective (UNFCCC, 2022). In contrast, countries face a dilemma between economic growth and sustainability due to low carbon emissions and natural depletion practices (Saufi *et al.*, 2016; Rehman *et al.*, 2021). Thus, the green growth (GG) concept emerges based on balancing economic growth and environmental enhancement (Zhao *et al.*, 2023).



Growth, usually measured in gross domestic product (GDP) today, is the economic measure of the market value of all final products produced in each period. Economic growth and environmental issues relationship are discussed carbon emissions resulting from economic activities, environmental degradation and resource use (Hickel and Kallis, 2020). GG, which expresses the implementation of sustainability policies in balance with economic growth, is placed at the center of sustainability policies by international organizations, especially the United Nations Environment Program and the Organization for Economic Cooperation and Development (OECD) (UNEP, 2022).

GG focuses on feasible economic growth while reducing resource use and carbon emissions. Economic, industrial and financial developments are crucial. New green technologies are fundamental to GG. Supporting green enterprises and innovation contributes to green technology. These investments are risky. Green finance products and risk management techniques should be developed to finance these investments. The production model and market change due to new technologies can provide economic transformation. Thus, the GG model includes macroeconomic and financial variables (Razzaq and Yang, 2023).

Sustainability has an essential role in many disciplines. Nevertheless, these studies analyze sustainability efforts from one perspective (renewable energy, recycling and misuse of natural resources) (Jiang and Ma, 2019; Abu-Qdais *et al.*, 2023). GG theory advocates integrated sustainability efforts and a total green economy transformation. Thus, early GG studies investigate the macroeconomic factors determining GG (Paroussos *et al.*, 2020; Scriciu *et al.*, 2013). However, some studies argue that innovation and human development, supported by adequate financing, have a vital impact on GG (Desalegn and Tangl, 2022). Studies focus on green agriculture and cities (Tian *et al.*, 2021).

The motivations of this study are to contribute to the limited GG literature in emerging markets, to analyze GG from a financial economy perspective and to determine the contribution of financial development and innovation to GG in Brazil, Russian Federation, India, China and South Africa and Türkiye (BRICS-T). Thus, we determine the macroeconomic and financial variables that affect GG in BRICS by panel data analysis from 2001 through 2020. Our research questions are: Do national income and personnel expenditure contribute to GG's economic and social progress in BRICS-T countries? Can foreign direct investments promote green transformation? Can financial development and innovation moderate GG?

BRICS-T countries are selected as a sample due to the following potentials (Baloch *et al.*, 2019b):

- (1) BRICS-T countries are the leading emerging countries. GG is a new story and green transformation may be easier for merging countries whose economic systems still need to be fully established.
- (2) The green transformation can contribute to resource utilization efficiency in BRICS-T countries, which have a significant portion of the world's resources.
- (3) Analyzing the factors affecting social progress in green transformation in BRICS-T countries, which have nearly half the world's population, can contribute to global green transformation efforts.
- (4) BRICS-T countries have regional and global influence.

Studies analyzing GG in BRICS-T countries are quite limited. Our research is original with its sample. Besides, the study model can contribute to the literature by addressing GG with social progress and green innovation dimensions. The findings and recommendations can help policymakers on GG transformation.

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This paper is organized as follows: We present the theoretical background in [Section 2](#), [Section 3](#) deals with the literature, [Section 4](#) describes methodology and data, [Section 5](#) discusses the empirical results, and we conclude this study in [Section 6](#).

## 2. Theoretical background

Sustainability involves ensuring that natural resources and ecological balance are maintained or preserved for future generations while meeting the needs of the present without compromising the ability of future generations to meet their own needs ([Hueting and Reijnders, 1998](#)). The concept of sustainability is not just limited to environmental or social aspects but also encompasses economic considerations. Economic sustainability refers to the ability of an economic system to support long-term growth and development without causing negative impacts on the environment or society ([French, 2002](#); [Pulido-Fernández et al., 2019](#)).

The sustainability literature finds complex implications for sustainability efforts' financial and macroeconomic results. The literature and practitioners emphasize a growth model compatible with sustainability rather than growth despite sustainability ([Chen et al., 2023a, b](#); [Azam, 2016](#)).

Environmental sensitivities and the concern about the negative impact of sustainability policies on economic growth are the basis of GG. The concept of GG developed in the Asia–Pacific region was presented at the Fifth Ministerial Conference on Environment and Development as a new policy beyond sustainable development. United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), OECD and World Bank create GG frameworks. In addition, the Global Green Growth Institute (GGGI), a nonprofit organization focusing on international GG studies, was established ([UNESCAP, 2023](#)).

GG represents the balance between economic growth and sustainability. Firstly, GG policies focus on two goals. GG aims to efficiently use natural resources and reduce environmental degradation and carbon emissions. Secondly, GG encourages the use of economy-friendly technologies in economic activities, cities and transportation by allocating research and development, finance and human resources to green transformation. There is no standard definition of GG. However, critical international organizations define GG in the following way ([The Sustainable Development Knowledge Platform, 2023](#)):

UNESCAP: Growth that emphasizes environmentally sustainable economic progress to foster low-carbon, socially inclusive development.

OECD: Fostering economic growth and development while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies.

World Bank: Growth that is efficient in its use of natural resources, clean in that it minimizes pollution and environmental impacts and resilient in that it accounts for natural hazards and the role of environmental management and natural capital in preventing physical disasters.

GGGI: GG is the new revolutionary development paradigm that sustains economic growth while at the same time ensuring climatic and environmental sustainability. It focuses on addressing the root causes of these challenges while ensuring the creation of the necessary channels for resource distribution and access to essential commodities for the impoverished.

GG theory is associated with classical economic growth. According to classical theory, economic growth is a function of physical capital, human resources and labor. However, new views on GG argue that natural sources should also be included in the growth function. The

idea that the productivity role of natural capital and the damage caused by environmental degradation can affect economic growth is the basis of GG theory (Smulders *et al.*, 2014).

$$\text{Economic Growth} = f(\text{Human Resource}, \text{Physical Capital}, \text{Labor})$$

Economic growth depends on the efficiency of the factors of production and the productivity of human capital. The efficiency of the labor market determines the production process and costs. Education and health expenditures affect labor. Human capital innovation increases the organizational success of research and development and businesses. Physical capital is the factor of production other than labor and land. Technological developments, foreign direct investments and a solid financial system improve physical capital (Solow, 1956). Capital accumulation is crucial for innovation, human capital investment and workforce improvement. However, capital accumulation without technological development will not provide sustainable economic and personal income growth. As a result of technological developments, externalities and policies, the income of households and businesses increases. Income increase positively affects consumption and savings. Thus, the economy grows faster (Smulders *et al.*, 2014).

In classical theory, the environment does not have a productive role despite the economic benefits. For this reason, the contribution of the environment to economic growth is ignored. However, environmental management can increase the efficiency of natural resources, human resources and physical capital. The impact of technological development and human resources on production may be limited and production may suffer without natural capital. There needs to be a higher elasticity of substitution between natural capital and other inputs in many strategic sectors, especially in food. In addition, environmental disasters can reach dimensions that make production impossible and human resource, labor and physical capital losses may occur. Thus, the GG theory argues that environmental capital will positively affect the production level (Hallegatte *et al.*, 2012).

$$\text{Economic Growth} = f(\text{Human Resource}, \text{Physical Capital}, \text{Labor}, \\ \text{Natural Capital}, \text{Green Innovation}, \text{Green Finance})$$

Natural capital can increase production levels. However, for economic growth, new job opportunities, capital, credit allocation and savings that will increase with employment increase are critical. Besides, eco-friendly investments and economic transformation can cause new costs for businesses. Therefore, GG is associated with financial development. These theories argue that financial development, financing green projects, small business and household adaptation to the green economy and carbon pricing will promote GG (Green Finance Hypothesis, Market-based Approaches Hypothesis, Access to Finance Hypothesis and Long-term Investment Hypothesis) (Lee, 2020; Stavins, 2003; Wang *et al.*, 2022a, b).

GG studies reveal variables affecting growth with resource use and low greenhouse gas (GHG) emissions. Empirical results show that green transformation may contribute to sustainable growth in agriculture, industry, transportation and city management (Wang *et al.*, 2022a, b; Resnick *et al.*, 2012; Liu *et al.*, 2022). In addition, innovation, financial development, education expenditure, human resource development, savings and green energy are essential variables that positively affect GG (Ahmed *et al.*, 2022; Verma and Kandpal, 2021).

Our model recalculates GDP based on carbon emissions, resource use and environmental degradation based on GG theory. Similarly, green innovation and human development are added to the model as vital elements of GG theory. Additionally, our model analyzing the existence and effectiveness of the green finance system in BRICS-T countries is based on the theories of green finance and access to finance.

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### 3. Literature review

GG is the coordination of sustainability policies with economic growth. Studies examine these efforts.

#### 3.1 *Green growth literature*

GG studies consider sustainable actions from a holistic perspective. Technological development is the subject of an essential part of GG studies. [Talebzadehosseini and Garibay \(2022\)](#) examine the impact of green products and technological innovation on GG in 61 countries. Partial Least Square-Structural Equation Modeling results show that green product significantly and positively affects GG. However, technological innovation does not affect GG. [Mensah et al. \(2019\)](#) analyze the impact of technological developments on GG in 28 countries by sector. According to the empirical results, the technological development of transportation in Ocean countries, production and processing of goods in Asian countries and energy technologies in European countries affect GG.

Population growth and resource use caused by urbanization are analyzed in GG studies. [Wang et al. \(2022a, b\)](#) analyze the effect of urbanization on GG in Belt and Road Initiative (BRI) region countries with the two-step system of generalized method of moments. Empirical results show that urbanization negatively affects GG. [Lee and Kim \(2016\)](#) emphasize that urbanization significantly affects GG, but the urban population moderates this effect. The GG awareness of the city population is crucial.

Green technology, cities and regulations are associated with human resource development. [Liu et al. \(2022\)](#) argue that the level of education has a positive effect on GG. Similarly, [Khan et al. \(2023\)](#) shows the significant impact of human capital on GG in G7 countries.

There is limited literature other than technological development, urbanization and human capital. These studies focus on the effect of GG on industry and labor market ([Kunapatarawong and Martínez-Ros, 2016](#)), the relationship between GG and political economy ([Resnick et al., 2012](#)) and the effect of green regulations on GG ([Dreyfus and Allemand, 2018](#); [Jang et al., 2010](#)).

#### 3.2 *Macroeconomic and financial green growth studies*

The impact of financial development on sustainability is studied mainly on energy use and carbon emissions. However, the concept of GG has gained importance in recent years. Studies do not constrain energy, carbon emissions and resource use and focus on models that support economic growth ([Bagheri et al., 2018](#)).

GG is the balance between economic growth and sustainability. For this reason, some studies deal with GG based on classical growth. These studies evaluate the theoretical sources that drive economic growth from the perspective of GG variables. Besides, studies examine whether GG is possible theoretically and empirically ([Hickel and Kallis, 2020](#); [Smulders et al., 2014](#)).

The drivers of GG are determined to create a feasible GG model. An essential part of the green studies analyzes the macroeconomic effect. [Wang and Shao \(2019\)](#) investigate the effect of macroeconomic variables on GG in G20 countries. Empirical results show that income per capita and gross research and development expenditures significantly affect GG. [Scricciu et al. \(2013\)](#) emphasize the importance of fiscal and monetary policies beyond carbon tax and pricing. [Caetano et al. \(2022\)](#) argue that foreign direct investment drives GG in emerging countries. [Chen et al. \(2023a, b\)](#) explore the role of macroeconomic soundness in GG. According to the Global Malmquist-Luenberger productivity index, Macroeconomic Stabilization Pentagon model and Kernel density estimation analyses, macroeconomic soundness significantly and positively affects GG in European Union countries. [Verma and](#)

Kandpal (2021) find that the Adjusted Net Savings rate significantly impacts sustainable growth in India. Chen *et al.* (2023a, b) examine the impact of green innovation and financial globalization on GG in BRICS-T countries. According to the cross-sectional-autoregressive-distributed lag (CS-ARDL) model, environmental patents positively affect GG. Cao *et al.* (2022) apply a panel data analysis to investigate financial development and innovation effects in China. The development scale of financial institutions (lnFDS) in the local province significantly negatively affects local GG. However, it significantly positively affects GG in the surrounding provinces. She and Mabrouk (2023) argue that foreign direct investments contribute to economic globalization, a precondition for a green economy. Studies argue that economic development can promote GG by positively affecting countries' investment climate and human resources. Besides, foreign direct investments can contribute to GG through technology transfer, investments and modernization through economic globalization.

Financing green technologies, production and consumption is crucial. Thus, GG studies include financial variables in the model. Zhang *et al.* (2023) emphasize allocating financial resources to human resources and research and development for GG in BRI countries. Authors find that green investment, credit and securities enhance China's economic growth and environmental quality. Zhao *et al.* (2023) draw attention to the moderating effect of green finance on the environmental quality of GG. This effect has apparent heterogeneity of countries' economic levels. Ahmed *et al.* (2022) analyze the effect of institutional quality and financial development in South Asian countries. Panel data analysis shows that financial development drives GG for an extended period. Gu *et al.* (2023) find that green finance efforts reduce carbon emissions in G7 countries. Xu *et al.* (2023) emphasize that green finance can promote GG by contributing to resource efficiency. Tan *et al.* (2023) analyze green economic growth in COP26.

Technology and human resource development are essential factors in green transformation. The GG literature argues that economic development and green finance will contribute to innovation and human resources (Chen *et al.*, 2023a, b; Jiakiu *et al.*, 2023; Liu *et al.*, 2023).

GG studies are limited. Most of the literature examines a specific country rather than analyzing a group of countries. These studies deal with Asian countries, especially China. This study examines the issue in emerging countries.

The model of the study is another crucial contribution to the literature. National income, personnel expenditure and foreign direct investment represent economic progress, social progress and economic globalization in the green economy transformation. Our model analyses GG regarding social and economic progress and the moderating role of financial development and innovation. Some studies find that economic progress, globalization and foreign direct investment determine sustainability efforts (Villanthenkodath and Pal, 2023). Studies argue that human development is essential in attracting innovation and investment (Lau *et al.*, 2023; Pal, 2023). Financial development and patent growth are moderating variables. Financial development can promote the investment climate for green transformation and economic globalization (Zhang *et al.*, 2023; Mahalik *et al.*, 2022; Lau *et al.*, 2022). Innovation is an important determinant for green transformation in production, urbanization and transport activities (Chen *et al.*, 2023a, b).

#### 4. Data and methodology

We investigate the economic and financial determinants of GG. Panel data analysis is applied in BRICS countries and Türkiye between 2001–2019. Since the CO<sub>2</sub> data is only available in this period, the 2001–2019 period is analyzed. The analysis sample is the countries that contain a significant part of the world economy and natural resources. Brazil, China, the Russian Federation, South Africa and India are BRICS countries. BRICS, which establishes economic cooperation with countries such as South Korea, Mexico and Türkiye, advocates increasing the weight of developing countries in the world economy (Wang and Huang, 2023).

Studies include BRICS countries with similar emerging countries in the analysis. We include Türkiye in the analysis due to its high growth potential, young population, geopolitical importance and being an important energy hub (Bacik, 2013; Yildirim *et al.*, 2022; Yasir and Önder, 2023).

GG is a proxy of the dependent variable. This study adopts the measurement of green economic growth used by Sohag *et al.* (2019) and Arif *et al.* (2022). They add education expenditures to GDP and subtract natural resource depletion and carbon emissions. Data are sourced from the World Bank World Development Indicators. Table 1 presents the list of variables.

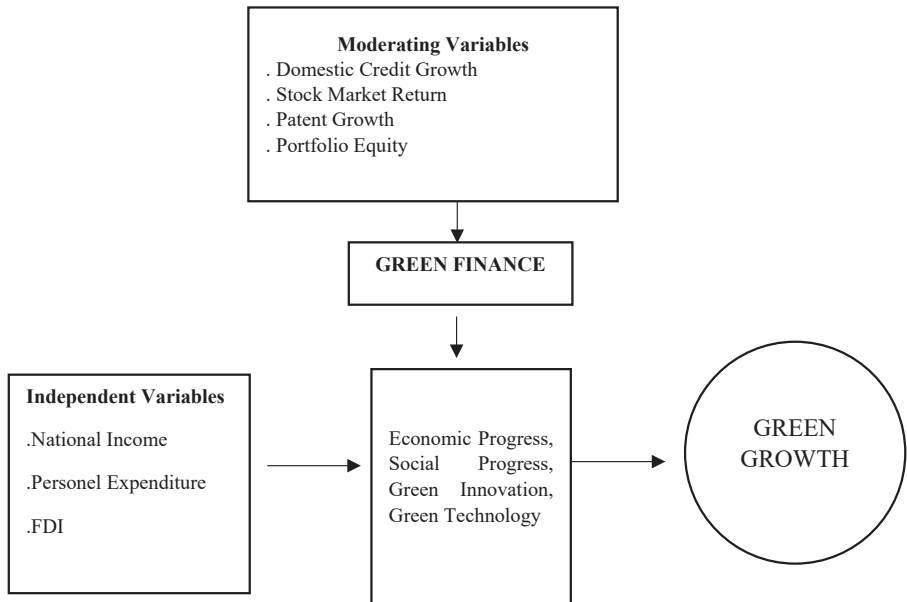
National income is one of the economic development indicators in a country. Economic progress is crucial for green investments and GG. The increase in national income positively affects intellectual capital, technological developments and human resources (Elliott, 2005; Gawrycka and Szymczak, 2021). Personnel expenditure increases social progress. Social progress may lead to sustainability awareness. Additionally, purchasing power can positively affect the use of green technologies in the city, transportation and production (Zhou *et al.*, 2020). Foreign direct investments and portfolio equity investments are critical for the investments of emerging countries. Foreign direct investments increase financial development and technological progress through investment, technology transfer and modernization by providing resources to emerging countries that need capital (Phiri and Ngeendepi, 2021). Figure 1 presents graphic visualization of the model.

Financial and technological developments can moderate the impact on GG. Financial development can boost the flow of capital towards sustainable investments and projects,

Variable name	Abbreviations	Definition
Green Growth (%)	GG	Gross Domestic Product + Education Expenditure (% of GNI)- Natural Source Depletion (% of GNI)- Energy Depletion (% of GNI) – C02 emissions (kt) growth (%)
Household consumption (%)	HC	Household final consumption expenditure is the market value of all goods and services purchased by households, including durable products. It excludes purchases of dwellings but includes imputed rent for owner-occupied dwellings. It also includes payments and fees to governments to obtain permits and licenses
Adjusted net national income growth (%)	NI	Adjusted net national income is GNI minus consumption of fixed capital and natural resources depletion
FDI inflows (% GDP)	FDI	Foreign direct investment, net inflows/GDP
Portfolio equity inflows (%)	PE	Portfolio equity includes net inflows from equity securities other than those recorded as direct investment, including shares, stocks, depository receipts, and foreign investors' direct purchases of shares in local stock markets
Stock market return (%)	SR	The stock market return is the growth rate of an annual average stock market index
Private credit by deposit money banks and other financial institutions to GDP (%)	PC	Private credit by deposit money banks and other financial institutions to GDP
Patent growth (%)	PTNT	Patent applications are worldwide patent applications

Source(s): World Bank (2023)

**Table 1.**  
List of variables



**Figure 1.**  
Graphic visualization  
of the model

**Source(s):** Authors' own work

such as green bonds, loans and guidance services that support environmentally conscious business practices. Access to financing for such initiatives can accelerate the transition towards a low-carbon economy and foster GG. Similarly, technological advancements can be instrumental in promoting GG by creating new and innovative technologies that minimize the environmental impact of economic activities (Sadorsky, 2010; Ponta *et al.*, 2021).

Based on the partition presented above, we put forward the following testable propositions:

- H1.* H0: National income does not significantly affect GG. If the null hypothesis is rejected, the results prove that national income can promote environmentally friendly behaviors and technologies in BRICS-T.
- H2.* H0: Household consumption does not significantly affect GG. If the null hypothesis is rejected, the results prove that The volume of green products and awareness of GG is sufficient in BRICS-T countries.
- H3.* H0: The impact of financial development and innovation on GG is insignificant. If the null hypothesis is rejected, the results prove that Green finance and innovation contribute to GG in BRICS-T countries.

To investigate the determinants of GG, we analyze GG as a function of macroeconomic, financial and innovation. The empirical model is as follows:

$$GG_{it} = \beta_0 + \beta_1 * HC_{it} + \beta_2 * NI_{it} + \beta_3 * FDI_{it} + \beta_4 * PE_{it} + \beta_5 * SR_{it} + \beta_6 * PC_{it} + \beta_7 * PTNT_{it} + \varepsilon_{it} \quad (1)$$

I stand for country and T stands for time. The coefficients of the regressors are denoted by  $\beta_{1-6}$ .  $\varepsilon$  is the error term. Panel data analysis can be applied as a fixed effect and random effect. The

correlation between regressors in the model determines the analysis. Hausman test is applied to determine the model. According to the Hausman test, the  $p$ -value is less than 0.05. For this reason, a fixed effect is chosen (Tabash *et al.*, 2022). Cross-sectional dependence is another test to determine the model. Cross-sectional dependence between units affects the choice of unit root testing. In the case of cross-sectional dependence, second-generation unit root testing is applied. Pesaran's cross-sectional dependence test model shows no cross-sectional dependence. Therefore, the first-generation unit root test is applied (Pesaran, 2007). Table 2 shows Hausman, cross-sectional dependence, autocorrelation and heteroscedasticity tests.

The autocorrelation and heteroscedasticity of the model are examined before panel data analysis. The systematic relationship between variables emerges as a result of the autocorrelation problem. We analyze the autocorrelation problem with the Baltagi Wu test. Results show that test values are less than 2, and the model has an autocorrelation problem (Born and Breitung, 2016). Heteroscedasticity refers to the variance difference between the error terms—heteroscedasticity of the model tests with the Modified Wald test. According to test results, there is a heteroscedasticity problem (Le *et al.*, 2020). There is no cross-sectional dependence problem in the model. However, there are autocorrelation and heteroscedasticity. Thus, we employ a robust standard error estimator. Parks-Kmenta, Beck–Katz and Driscoll–Kraay estimators yield more robust outcomes when the model has heteroskedasticity and autocorrelation. Specifically, when the number of N exceeds the number of periods (T), the Driscoll–Kraay estimator demonstrates greater robustness. In contrast, the Parks-Kmenta estimator offers improved accuracy when T surpasses N (Mehic *et al.*, 2013; Tobechukwu and Azubuike, 2020). The Parks-Kmenta model is as follows:

$$Y_{it} = \beta_1 + \sum_{k=2}^k \beta_k \chi_{kit} + \mu_{it}$$

Financial development provides the necessary investments for the green economy transformation. Furthermore, access to financial resources contributes to human development and consumption of green products. Similarly, economic development not supported by innovation cannot contribute to green growth (Chen *et al.*, 2023a, b). Therefore, both the individual effect and the moderator effect of these variables are examined (Saha and Yap, 2014).

Interactive regression modeling (IRM) analyzes the moderator effect of financial development and innovation. IRM is a statistical technique used to model the relationship between two or more variables, especially when the relationship between them may not be linear or interactive. It is a flexible approach that can deal with complex relationships and help identify how one variable's effects depend on another (Moon and Weidner, 2017).

Panel A: Hausman test <i>p</i> -value	0.0000
Panel B: Pesaran's cross-sectional dependence test <i>p</i> -value	0.2247
Panel C: Autocorrelation test Durbin Watson	1.530526
Baltagi Wu LBI	1.631304
Panel D: Modified Wald test Prob > $\chi^2$	0.0005
Source(s): Authors' own work	

**Table 2.**  
Hausman test, cross-sectional dependence, autocorrelation, and heteroscedasticity test

## 5. Empirical results

Table 3 presents descriptive statistics for the strongly balanced panel data set for six countries and 114 country-time observations. Russia has the lowest GG rate. The maximum GG rate is in Türkiye. Similarly, Türkiye has the best average GG performance. Russia has the lowest average GG in the sample period. Russia is a country that stands out among the BRICS countries with its rich natural resources. Russia is at the top of the world's raw material trade thanks to its natural gas, oil, mineral deposits and forestry resources (Kuteleva, 2020). As a result of investments in renewable energy and waste management in recent years, Türkiye is positively differentiated from other countries in terms of GG. Türkiye's use of renewable energy is above the European Union (EU) average (Erol *et al.*, 2022).

Table 4 shows the correlation matrix. The level of correlation between independent variables is below 50%. There is a low and moderate correlation between the independent variables. Hence, the multicollinearity problem cannot be mentioned.

Table 5 shows the results of the Levin–Lin–Chu (LLC) unit root test. Akaike information criteria are used for the optimal length. All variables are stationary at the level except for household consumption and patent growth. The first differences of these variables are analyzed.

We test the determinants of GG in BRICS-T countries with the Parks-Kmenta estimator in Table 6. National income growth, household expenditure, foreign direct investment and portfolio equity investment represent macroeconomic variables. Credit and stock market development is a proxy for financial development. Patent application growth is a measure of innovation.

Empirical results show that household consumption negatively affects GG. Personnel expenditure is crucial for social progress. Household consumption is one of the factors that ensure economic development. Despite this, studies argue that household consumption may positively affect sustainability with sustainability education, green technology, renewable energy and clean transportation (Shittu, 2020; D'Alessandro *et al.*, 2020). Additionally, an increase in household consumption can reduce savings. For this reason, GG investments may be adversely affected (Drechsel-Grau and Schmid, 2014). Our results support these views. Studies examining the effect of household consumption on GG are quite limited. Lorek and Spangenberg (2014) argue that sustainable household consumption can positively affect GG. However, institutional transformation and household education are essential for this impact. Paroussos *et al.* (2020) emphasize that household consumption is one of the determinants of GG. This effect depends on the household's access to finance. Our findings are consistent with these studies. Household consumption in sample countries cannot contribute to GG.

National income has a positive impact on GG. National income increase represents economic power and intellectual capital (Heal and Kriström, 2005). Some theories suggest that economic development can lead to environmental degradation due to increased resource use

Variable	Obs	Mean	Std. Dev	Min	Max
GG	114	3.55	6.38	-19.04	14.28
HC	114	55.81	9.08	34.32	65.31
NI	114	0.09	0.15	-0.32	0.54
FDI	114	2.21	1.18	0.20	5.36
PE	114	-0.03	12.79	-57.56	112.21
SR	114	9.32	24.65	-53.50	161.14
PC	114	73.61	41.12	14.01	165.39
PTNT	114	0.07	0.16	-0.54	0.94

**Table 3.**  
Descriptive statistics

**Source(s):** Authors' own work

	GG	HS	NIG	FDI	PE	SMR	CRD	PTNT	Financial determinants of green growth
GG	1.0000								
HS	0.1333	1.0000							
NIG	0.1217	-0.2307	1.0000						
FDI	-0.0844	-0.3087	0.0240	1.0000					
PE	0.0564	0.0344	-0.1366	-0.0807	1.0000				
SMR	0.2237	0.0664	0.2288	-0.0017	-0.0074	1.0000			
CRD	0.2213	-0.3832	-0.1550	0.0571	0.2010	-0.0306	1.0000		
PTNT	0.2499	-0.2486	0.0543	0.3133	0.1319	0.0735	0.1637	1.0000	

**Source(s):** Authors' own work

**Table 4.**  
Correlation matrix

	Level	First difference
GG	-3.9590* ** **	-1.4667*
HC	-0.8074	-2.9470* **
NI	-2.0380* **	-10.1235* ** **
FDI	-2.1054* **	-6.1865* ** **
PE	-4.6449* ** **	-12.4639* ** **
SR	-4.1321* ** **	-4.8914* ** **
PC	-3.9442* ** **	-2.2797* **
PTNT	-0.6644	-5.5077* ** **

**Note(s):** \*, \*\* and \*\*\* indicate the significance at the 10, 5 and 1% levels, respectively  
**Source(s):** Authors' own work

**Table 5.**  
Unit root test

	p-value	Coef
D.HC	0.000* ** **	-0.733
NI	0.000* ** **	6.493
FDI	0.536	0.616
PE	0.029* **	0.022
SR	0.000* ** **	0.020
PC	0.000* ** **	0.040
D.PTNT	0.536	0.616

**Note(s):** \*, \*\* and \*\*\* indicate the significance at the 10, 5 and 1% levels, respectively  
**Source(s):** Authors' own work

**Table 6.**  
Empirical results of  
Parks-Kmenta  
estimators

and carbon emissions (Sorrell, 2007). Conversely, others argue that economic growth and green transformation can mitigate environmental impacts (Chatzistamoulou and Tyllianakis, 2022). Wang and Shao (2019) find that income per capita positively affects GG in G20. Khoshnava *et al.* (2020) emphasize the importance of national income in integrating a green economy into production and consumption activities. In this manner, our results are consistent with previous studies.

The fixed effect model confirms the statistical significance of stock market returns, which promote GG. Previous research highlights the role of stock market development in sustainability, emphasizing how it boosts clean energy consumption through sustainability awareness and liquidity (Kutan *et al.*, 2018; Sadorsky, 2011). Similarly, domestic credit to the private sector positively impacts GG. The similar effect of credit and stock market variables

on GG is reasonable. [Sadorsky \(2011\)](#) argues that the effects of the banking system and the stock market on sustainability are interrelated. Portfolio equity inflows positively affect GG. Emerging countries have a capital shortage and need foreign resources. Foreign investments can contribute to financial soundness and innovation in emerging countries ([Alderighi et al., 2019](#)).

[Tables 7 and 8](#) show the moderator effect of financial and technological development. According to [Table 7](#), the moderator effect of financial development variables is statistically insignificant. Similarly, [Table 8](#) shows that patent growth cannot moderate the impact of independent variables on GG.

According to our findings, [Hypothesis 1](#) can be rejected. However, Nevertheless, household consumption negatively affects GG. Thus, [hypothesis 2](#) is accepted. [Tables 7 and 8](#) show that the moderating effect of financial development and patent increase on GG in BRICS-T countries is insignificant. We accept the [hypothesis 3](#).

The findings have implications for BRICS-T countries. In emerging countries, national income can positively affect economic development, foreign direct investment attraction, promotion of social services, investment and quality of life ([Lopes et al., 2002](#)). GG can also share in this development. The negative effect of personal expenditures on GG indicates that the daily use of green products is low and green awareness needs to be formed in BRICS-T. While moderator variables reveal the need for a green financial system and alternative financing needs in BRICS-T countries, green research and development activities are insignificant ([Chen et al., 2023a, b](#)). Nowadays, BRICS countries have tried to determine common financial policies. These policies should define green finance and green products and offer instruments. Similarly, BRICS needs a common energy policy. Some BRICS countries are energy exporters and some are energy-dependent ([Udeagha and Ngepah, 2023](#)). In summary, BRICS countries with different economic structures and resources should develop a common GG policy integrated into their existing common policies.

	<i>p</i> -value	Coef
D.HC	0.044* **	-0.899
NI	0.047* **	7.254
D.HC*SR	0.924	0.000
D.HC*PC	0.318	0.006
D.HC*PE	0.969	-0.000
NI*SR	0.291	0.058
NI*PC	0.405	-0.029
NI*PE	0.405	0.089

**Table 7.**

The moderator effect of financial development

**Note(s):** \*, \*\* and \*\*\* indicate the significance at the 10, 5 and 1% levels, respectively  
**Source(s):** Authors' own work

	<i>p</i> -value	Coef
D.HC	0.005* ** ***	-0.554
NI	0.000* ** ***	6.104
D.HC*DPTNT	0.931	-0.070
NI*DPTNT	0.862	1.269

**Table 8.**

The moderator effect of technological development

**Note(s):** \*, \*\* and \*\*\* indicate the significance at the 10, 5 and 1% levels, respectively  
**Source(s):** Authors' own work

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## 6. Conclusions and policy implication

This study aims to determine the macroeconomic and financial variables that affect GG in BRICS-T countries. According to panel data analysis, national income growth positively affects GG. Economic development in BRICS-T countries promotes GG efforts. Wealthy countries contribute to the transition to an eco-friendly economy. Household consumption harms GG. Sustainability awareness of households, the cost of sustainable products and limited green products in BRICS-T countries may cause this result. Results show that foreign direct investments support a sustainable economy. Financial development and patent growth are moderator variables in the model. Empirical results show that the moderating effect of financial development and patent growth is insignificant.

Household consumption reduces GG in BRICS-T. Businesses can create and manufacture eco-friendly products, employ renewable energy sources and integrate sustainable practices within their supply chains. Additionally, they can encourage consumers to adopt more sustainable behaviors by implementing marketing and educational initiatives. Households can adopt sustainable behaviors, such as reducing energy consumption, minimizing waste and choosing environmentally friendly products. They can also support local businesses prioritizing sustainability and advocating for policy changes promoting GG. Policymakers can establish regulations and incentives encouraging sustainable consumption and production, including implementing carbon pricing, subsidies to support renewable energy and taxes on products with negative environmental impacts. Additionally, they can invest in green infrastructure and facilitate the transition towards a low-carbon economy. Besides, policymakers should increase the sustainability awareness of households through education and campaigns.

National Income has a positive effect on GG. Increasing National Income provides benefits beyond economic results and can improve the quality of human resources. Businesses substantially influence national income growth by contributing to economic activity and job creation. They can further promote national income justice by providing fair wages, ensuring favorable working conditions and investing in the communities where they operate. Households contribute to national income growth by participating in the labor market and consumption activities. They can promote national income justice by advocating for policies that support fair wages and social protections.

Financial markets and investors have a crucial role in advancing GG. They can promote sustainability and environmental responsibility by creating and investing in financial products and instruments such as green bonds, green mutual funds and socially responsible investment portfolios. BRICS-T countries should establish a financial system to promote GG. Alternative financing instruments can be developed to finance GG, a GG stock market index can be established and the borrowing costs of enterprises contributing to GG can be reduced.

According to the analysis results, the moderating effect of patent growth is insignificant. Governments should support green innovation with research and development funds, market incentives and tax breaks. Besides, a green innovation regulatory framework should be prepared to regulate education policies and collaboration with universities, the private sector and research centers and the market. Businesses should adapt the green management system to their activities.

We have some limitations. Due to the inaccessibility of some data, the study is limited to the period 2001–2019. Future studies may analyze a broader sample period. Moreover, further studies can include variables representing the GG perception of households and businesses in the model. Diversification of GG calculations is also crucial for future studies.

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### Corresponding author

Bertaç Şakir Şahin can be contacted at: [bertacsa@yildiz.edu.tr](mailto:bertacsa@yildiz.edu.tr)