Environment, Development and Sustainability
https://doi.org/10.1007/s10668-025-06034-5

Calculation of sustainable development index and empirical analysis: the case of BRICS-T countries

Mücahit Ülger[1] · **Ahmet Kasap**[2]

Received: 6 February 2024 / Accepted: 29 January 2025

Abstract
In recent years, increasing economic competition between countries has brought environmental pollution and carbon emissions. Especially in developing countries, the flexibility in the implementation of laws causes this pollution to increase even more. Taking environmentally friendly measures on a global scale while developing both economically and socially is defined as sustainable development. Sustainable development is a priority research area at the country and regional level and has become the new goal of world development. The aim of the study is to create a Sustainable Development Index for BRICS-T countries by compiling data from the OECD. The variable pool used in the applied method is quite wide and is basically divided into three groups: economic, environmental and result indicators. Additionally, another aim of the study is to examine the relationships between external debt stock, R&D expenditures and renewable energy use in the Sustainable Development Index. In the analysis conducted using the Panel ARDL method, while no relationship was found between the external debt stock and the Sustainable Development Index for BRICS-T countries, it was concluded that there was a negative relationship between R&D expenditures and the Sustainable Development Index, and a positive relationship between the use of renewable energy and the Sustainable Development Index.

Keywords Sustainable development index · BRICS-T · Panel ARDL · Empirical analysis

✉ Mücahit Ülger
mucahit.ulger@ahievran.edu.tr

Ahmet Kasap
ahmet.kasap@gop.edu.tr

[1] Mucur Vocational School, Kırşehir Ahi Evran University, Kırşehir, Türkiye

[2] Turhal Faculty of Applied Sciences, Tokat Gaziosmanpaşa University, Tokat, Türkiye

Published online: 10 February 2025

1 Introduction

Sustainability is seen as a feature of a situation or process that can be maintained indefinitely. Development, on the other hand, is expressed as an environmental change that requires in-depth intervention in nature and consumes natural resources. Both concepts come together under the umbrella of sustainable development. Sustainable development does not mean anything on its own. In fact, sustainable development is achieved through the management of factors such as environmental, natural, economic, social, cultural and political. Therefore, these issues are closely related to each other and it is not possible to deal with them independently (Sage, 1999).

Inter-generational equity, one of the fundamental driving forces behind the concept, requires considering the needs of future generations while meeting the needs of today (Jabareen, 2008; Jeronen, 2020). Based on all these concepts expressed here, sustainable development is defined as development that meets today's needs without compromising the ability of future generations to meet their own needs (Brundtland, 1987).

The temporal and dynamic aspects of sustainability are emphasized in the definition. The definition of sustainable development shows that the needs include a just society and a healthy economy (Jeronen, 2020). In this sense, sustainable development can be seen as a criterion of environmental justice. In sustainable development, the basic idea is that each generation leaving an inheritance a production structure that is at least as broad as it inherited from the previous generation, according to the current demographic structure. If this is the case, it means that the economic and production opportunities of the next generation will be better than the previous generation (Dasgupta, 2007). Therefore, sustainability is a very important concept for both present and future generations and it will continue to be so (Garetti & Taisch, 2012). In addition, the ethics underlying the concept of sustainable development have been questioned by some researchers. In particular, Kothari (1990) argued that the concept of sustainability is an empty term and that the current development model destroys the richness of nature and is therefore not sustainable.

Irregular social, economic, ecological developments and regional inequalities are considered as the main problems of the last century. That sustainable development is still an important concept was once again clearly demonstrated at the United Nations-The 2023 Sustainable Development Goals Summit held in September 2023. The Sustainable Development Goals remain one of the core elements of the United Nations 2030 agenda. Within the framework of these goals, the 2030 agenda has been set to transform the world by ensuring human well-being, economic well-being and environmental protection at the same time.

Besides all these, sustainable development plays an important role in the business world and industry in today's century (Krajnc & Glavič, 2005). It is widely accepted that firms play an important management role in addressing sustainable development pressures. That's why it has become a part of the operational and competitive strategies of many companies (Angell & Klassen, 1999). In addition, in recent years, society has begun to demand that companies implement policies for sustainable development. For this reason, companies have begun to contribute to sustainable development by reviewing their operations and processes (López et al., 2007).

Although sustainable development is an important issue today, there is still no accepted method to measure the level of sustainable development. Therefore, the main purpose of the study is to create a Sustainable Development Index (SDI) for BRICS-T countries by compiling data from OECD (The Organisation for Economic Co-operation and Development). This created SDI covers groups of economic, environmental and social indicators. Here, the economic indicator means that existing resources provide long-term economic benefits sufficient for the production system, the environmental indicator means the protection of life forms existing on earth, and the result indicator means reducing poverty (Goodland, 1995). Concerns about the degradation of natural resources lead researchers to search for a single indicator to measure sustainability at the country level (Turturean et al., 2019). This index covers the internal nature, green growth and social dimensions of sustainable development. In addition, the relationships between R&D (Research and Development) expenditures, renewable energy use, external debt stock and SDI in the BRICS-T countries in the period 1991–2019 are analyzed statistically. The variables used are R&D expenditures, renewable energy usage, and external debt stock, as they directly influence the fundamental dynamics of sustainable development. External debt stock determines countries' economic development and investment capacities, while R&D expenditures promote innovation and technological advancement, contributing to economic growth and environmental sustainability. Renewable energy usage supports sustainable development by meeting energy needs without causing environmental harm compared to fossil fuels. Analyzing the impacts of these variables on sustainable development will assist policymakers in developing more effective strategies. In doing so, three different research hypotheses are proposed, detailed below.

H1 R&D expenditures in BRICS-T countries are expected to positively influence SDI.

H2 Renewable energy usage in BRICS-T countries is expected to positively influence SDI.

H3 External debt stock in BRICS-T countries is expected to negatively influence SDI.

Sustainable development, although an intriguing topic, has been addressed by relatively few researchers (Barrera-Roldán & Saldívar-Valdés, 2002; Khanova et al., 2021; Peng & Zhang, 2022; Salvati & Carlucci, 2014) who have calculated SDI in different country or country group contexts. Studies in the literature aimed at developing sustainable development indices have made significant contributions to measuring and analyzing various dimensions of sustainable development. These studies have evaluated sustainable development performance using multidimensional approaches that incorporate economic, environmental, and social indicators. Within this framework, the motivation of this study is to compile OECD data to construct an SDI specifically tailored for BRICS-T countries in the context of Sustainable Development Goals.

In our study, the primary reason for using the sustainable development index created by the OECD is its alignment with the indicators that better fit our research question. While the UNDP index focuses more on human development and social indicators, the OECD index comprehensively covers economic and environmental indicators in detail. This aspect significantly facilitates the analysis of economic components of sustainable development policies, especially in BRICS-T countries. Additionally, the more current and accessible nature of OECD datasets enhances the reliability of our research findings. These methodological differences between the UNDP and OECD indices illuminate our study's methodological preferences and ensure its structured alignment with our research objectives. These distinctions between the UNDP and OECD indices contribute to broadening the scope of our study and enhancing the validity of our findings.

BRICS-T countries exert significant influences on sustainable development indicators due to their unique economic and political characteristics. Rapid economic growth, high R&D expenditures, and renewable energy potential shape the economic dynamics of these countries, while external debt stock and political stability directly impact sustainable development. Strong governance structures and environmental regulations support the implementation of sustainable development policies, and international collaborations accelerate this process. In this context, the experiences of BRICS-T countries offer valuable lessons and strategies for achieving sustainable development goals in other developing economies.

However, each country varies in its economic development level, political stability, environmental policies, and innovative capacity. For instance, China's high R&D expenditures and investments in renewable energy positively contribute to sustainable development efforts. Meanwhile, Russia's dependency on the energy sector and environmental issues pose challenges to sustainability. Countries like India and Brazil face environmental and social sustainability issues alongside rapid population growth and economic expansion.

The main reason for selecting BRICS-T countries is their significant role as examples in economic growth and development. Comprising Brazil, Russia, India, China, South Africa, and Turkey, the BRICS-T group are among the developing economies whose global economic shares and impacts are increasing. Despite having different economic, social, and environmental dynamics, these countries face similar challenges and opportunities in achieving sustainable development goals. Moreover, BRICS-T countries provide extensive and diverse datasets for studying the impacts of factors such as renewable energy usage, R&D expenditures, and external debt stock on sustainable development. In this context, the analysis of BRICS-T countries will contribute to obtaining important and generalizable results for determining Sustainable Development Index (SDI) indicators.

SDI has been studied at various levels in different countries (Hickel, 2020), including Italy (Salvati & Carlucci, 2014), rural municipalities in Galicia (López-Penabad et al., 2022), 163 countries worldwide (Jin et al., 2020), 188 countries (Peng & Zhang, 2022), the EU and Ukraine (Khanova et al., 2021), China (Wang et al., 2024), developed and developing countries (Sakalsız & Kılıç, 2024), Indonesia (Thamrin et al., 2023), and BRICS countries (Andronova & Sakharov, 2022). However, a comprehensive SDI framework has not yet been established for BRICS-T countries. Building on this gap, our study aims to contribute to the existing literature in three key ways. Firstly, it is one of the few studies analyzing the methodological differences between OECD and UNDP sustainable development indices and their impact on research outcomes. Our study allows for a detailed examination of the economic components of BRICS-T countries by focusing on the OECD index's economic and environmental indicators. Secondly, using the Panel ARDL method, our analysis reveals the relationships between external debt stock, R&D expenditures, renewable energy usage, and the sustainable development index in BRICS-T countries. This method is rarely employed in the literature to determine long-term relationships between variables. Thirdly, the study establishes a sustainable development index for countries like BRICS-T that are significant examples of economic growth and development, thereby providing a new and comprehensive dataset for evaluating sustainable development policies in these countries. However, the study is constrained by the time period considered. While the analysis covers the years 1991–2019 for BRICS-T countries, data limitations mean that index values begin in 1992 for Turkey and 1994 for Russia.

The study consists of 4 parts. After the introduction, the rest of the study is organized as follows: a short literature review is included in the second section. In the third section, the variables were introduced and the Sustainable Development Index was created. In the fourth chapter, the method is introduced and econometric application is included. In the fifth section, final evaluations are presented.

2 Literature review

This section reviews significant studies on the development of sustainable development indices. The literature focuses on various methodological approaches and applications. Some studies have developed regional-scale methodological approaches to create SDIs at the local level, demonstrating the effectiveness of these indices in measuring sustainability performance. Other studies have integrated economic, social, and environmental dimensions to develop comprehensive sustainable development indices, highlighting international inequalities through these indices.

These studies in the literature emphasize the diversity and methodological flexibility in developing sustainable development indices. Most of the research has been designed to contribute to national-level policymaking and decision-making processes, enabling comparisons of sustainability performance across different geographic regions.

The importance of sustainable development indices in the literature is increasingly recognized because these indices help us understand the relationships between environmental, economic, and social sustainability. For instance, some studies have used SDI to compare the effectiveness of environmental policies across different countries by evaluating environmental sustainability. Other research examines the impacts of economic growth and social development on sustainability, emphasizing the importance of a balanced approach in achieving sustainable development goals. These studies demonstrate that the development and implementation of sustainable development indices contribute to the creation of effective strategies for addressing various sustainability challenges globally.

When examining the literature regarding the creation of SDIs and methodological approaches, different researchers have developed various methodologies to construct sustainable development indices. Barrera-Roldán and Saldívar-Valdés (2002) developed a methodology by applying SDI to seven municipalities in the Coatzacoalcos river basin in Mexico to create SDI within the framework of the Drivers, States, and Responses (DSR) philosophy, using multi-criteria decision theory. The analysis identified the most urgent issues to be addressed to improve sustainability and resource management criteria in municipal development. Similarly, Salvati and Carlucci (2014) utilized a Factor Weighting Model (FWM) supported by exploratory statistics and spatial analyses at the local scale in Italy to develop SDI. This index revealed a spatially complex distribution with a pronounced north-south gradient reflecting classical socio-economic inequalities observed between competitive and disadvantaged regions in Italy. Luan et al. (2017) developed a comprehensive index based on sensitivity analysis of 18 indicators taken from an existing index. The Extended Fourier Amplitude Sensitivity Test (EFAST) was used to quantitatively determine the importance of sustainable development indicators, highlighting the need to simplify the assessment process of sustainable development due to the overabundance of such indicators. Jiang and Shi (2023) created an enhanced sustainable development index by maintaining the basic formula of the SDI but replacing the ecological footprint with agricultural disaster intensity.

In the context of regional or national SDI applications and analyses, various studies have been conducted to assess the environmental sustainability of different countries' production and consumption patterns using SDI. Hickel (2020) developed SDI to evaluate the environmental sustainability of production and consumption models in different countries. Countries like Norway and the United Kingdom, despite being leaders in achieving Sustainable Development Goals, rank poorly in environmental sustainability. Jin et al. (2020) measured the National Sustainable Development Index (NSDI) for 163 countries worldwide and compared it with HDI and other well-known development indices. The results demonstrated that NSDI is a reliable and relatively comprehensive index for assessing sustainable development, addressing deficiencies in existing indices. Singh et al. (2021) obtained the Global Sustainable Development Index by combining economic development, environmental sustainability, and social development indices using panel data at the country level. The study investigated the impact of environmental technologies, deforestation, and the three indices on the global sustainable development index. Due to the socioeconomic diversity among the countries considered, high inequality in their sustainable development was identified. Khanova et al. (2021) calculated SDI in the EU and Ukraine, determining that Germany, Denmark, Finland, Ireland, Luxembourg, the Netherlands, and Sweden have the highest economic development among EU countries. The highest social development among EU countries was found in Austria, Germany, Denmark, Finland, Luxembourg, the Netherlands, Portugal, and Sweden, while Bulgaria, Greece, Hungary, Romania, and Ukraine were identified as countries with specific social issues. Peng and Zhang (2022) included 189 countries (regions) in their HDI rankings, excluding Liechtenstein due to significant data gaps. Based on the 2019 SDI data survey covering 188 countries (regions), the study concluded that rankings of oil-producing countries sharply declined due to ecological land degradation and single-industry structures. Southeast Asia and East African countries (regions) showed progress in rankings due to ecological conservation efforts, while the main reason for ranking changes in most developing countries (regions) was unequal land allocation. Sun et al. (2022) adopted and modified the National Sustainable Development Index, which includes 12 indicators, evaluating the sustainable development status of 179 countries from 2010 to 2016. The results indicated no significant trend towards narrowing or widening the gap in sustainable development levels among countries during this period.

There are various studies within the scope of SDI encompassing environmental, economic, and social dimensions. Li et al. (2022) analyzed SDIs related to shale gas usage in China, considering environmental, economic, and social demands through an analytic hierarchy process and compared them with the United States and the United Kingdom. The United States and China exhibited higher SDIs compared to the United Kingdom. Andronova and Sakharov (2022) comparatively analyzed the sustainable development indices of BRICS countries and evaluated their progress towards the United Nations' sustainable development goals from 2015 to 2020. Destek et al. (2023) explored the applicability of the natural resource curse theory through a sustainable development index, contrasting with traditional research. Covering 23 countries at risk of natural resource curses from 1990 to 2019, the study analyzed the impacts of natural resource rents, human capital index, institutional quality, financial development, and trade openness on sustainable development indices. Findings indicated that sustainable development faces challenges similar to natural resource curses. Thamrin et al. (2023) created a multidimensional composite index called the Regional Sustainable Development Index (RSDI) to measure regional sustainable development performance in Indonesia. A significantly positive relationship between RSDI and HDI suggests consistent progress between the two measures. RSDI in Indonesia can be classified as medium to high; however, two provinces (East Nusa Tenggara and Papua) exhibit low RSDI. Wang et al. (2024) developed a regional sustainable development index (RSDI) aimed at measuring China's progress towards local Sustainable Development Goals from 2013 to 2020. RSDI in eastern China decreased annually by 0.32%, while it increased by 1.26% annually in central and western regions. RSDI in northern China decreased annually by 0.14%, whereas in southern regions of China, it increased annually by 2.62%. Sakalsız and Kılıç (2024) aimed to examine the relationship between SDI, Globalization Index, and financial development among developed and developing countries from 1990 to 2019. They found that as globalization increases in both developed and developing countries, SDI increases in the long term. Financial development negatively affects SDI in the long term for both developed and developing countries.

There are also studies that calculate SDIs with humanitarian and demographic dimensions alongside environmental, economic, and social dimensions. Bravo (2014) introduced the Human Sustainable Development Index by adding an environmental dimension to the Human Development Index. López-Penabad et al. (2022) developed a sustainable development index for rural municipalities by including a demographic indicator in addition to three indicators (economic, social, and environmental). Hai et al. (2022) aimed to assess the level of sustainable development using SDI for two regions, Ly Son and Phu Quy islands. The results demonstrate the suitability of SDI in predicting the level of sustainable development for island regions in Vietnam.

3 Creating a sustainable development index

Since the World Summit held in 1992, numerous efforts have been made to measure sustainable development (UNDESA, 1992; Moffatt, 1996). In this context, today there are over 500 scales used by various public institutions, organizations, and non-governmental organizations to measure sustainable development (Parris & Kates, 2003). Among the global scales are the United Nations Commission on Sustainable Development Sustainable Development Index (UNCSD-SDI), the Happy Planet Index (HPI), the Living Planet Index (LPI), Ecological Footprints (EF), the Environmental Sustainability Index (ESI), the Environmental Performance Index (EPI), and the Human Development Index (HDI). While most of these indices consider the three dimensions of sustainability (economic, environmental, and social), UNCSD-SDI and SDGI address one or two of these dimensions (Mori & Christodoulou, 2012).

There are many different methods in the literature for creating a Sustainable Development Index (SDI). Although the pool of variables used in these methods is quite extensive, they are generally grouped into the three categories mentioned earlier. Social indicators have been evaluated as outcome indicators in some sources. The indices used by the United Nations, the European Union, and the OECD are the most commonly used for SDI. In this context, the variables used in the OECD's SDI were chosen for this study, considering the accessibility of the data.

3.1 Selection of variables

While selecting variables for the sustainable development indicator, all indicators based on the economic, environmental and result indicators used by the OECD were included in the index calculation. The more variables there are, the more accurately the created index will be calculated. However, indicators that do not have observation values or indicators with missing data belonging to the selected country group are not included in the calculation. The variables and their sources for which observation values were obtained are given in Table 1.

The weighting of components can vary for each country and economy. Since this study aims to create a basic index that could inspire future research, it was decided to assign equal weights to the components. When determining the weights of the components, consulting experts in the field or conducting surveys with specialists can be considered. However, to ensure that the focus of this study remains on creating the index rather than on weighting, no survey was conducted.

3.2 Normalization of variables

Variables expressing economic value usually have different units and scales. Creating an index using variables at different scales will reduce the reliability of the index. Therefore, it is necessary to normalize variables at different scales.

In addition, it is a positive situation that some variables increase and others decrease. Therefore, it is necessary to pay attention to this situation when normalizing the variables. Normalization should be made using the benefit or cost criterion formula depending on the situation of the variable (Al, 2019).

Benefit criterion formula:

$$x_i' = \frac{x_i - \min(x_i)}{\max(x_i) - \min(x_i)}$$

Cost criterion formula:

$$x_i' = \frac{\max(x_i) - x_i}{\max(x_i) - \min(x_i)}$$

As a result of applying the appropriate formula to each variable, the values of all variables are normalized by reducing them to the range [0,1]. In addition, through the cost and benefit criterion, a decrease in the value of the normalized variables obtained indicates a negative situation, while an increase indicates a positive situation.

After the normalization stage, different weights or equal weights can be given to the variables depending on their relative importance in creating the index. Since any of the economic, environmental and outcome indicators are not less important in terms of sustainable development, it is assumed that the contribution of each to the index is equal.

Table 1 Selected variables

Variable Group	Variable	Criterion Direction	Source
Economic Indicators	Current account balance (% of GDP)	Benefit	World Bank
	FDI, net inflows (% of GDP)	Benefit	World Bank
	Total reserves (including gold and current US dollars)	Benefit	World Bank
	GDP growth per capita (annual %)	Benefit	World Bank
	Unemployment (international labor organization estimate)	Cost	World Bank
Environmental Values	Total greenhouse gas emissions (kt CO2 equivalent)	Cost	World Bank
	CO2 emissions (kt)	Cost	World Bank
	Nitrous oxide emissions in the energy sector (thousand metric tons of CO2 equivalent)	Cost	World Bank
	Methane emissions (kt CO2 equivalent)	Cost	World Bank
	Nitrogen oxide emissions (thousand metric tons of CO2 equivalent)	Cost	World Bank
	Energy efficiency, GDP per unit total energy consumption	Benefit	World Bank
	Water stress level: Freshwater withdrawal as a proportion of available freshwater resources	Cost	World Bank
	Forest area (% of land area)	Benefit	World Bank
Result Indicators	Gini WID	Cost	World Inequality Database
	Labor force participation rate (% of total population aged 15+) (international labor organization estimate)	Benefit	World Bank
	Life expectancy at birth, total (years)	Benefit	World Bank
	Mortality rate, under 5 (per 1,000 live births)	Cost	World Bank
	Age dependency ratio (% of population of working age)	Cost	World Bank
	Final consumption expenditure of households and NPISHs (% of GDP)	Cost	World Bank
	Death due to exposure to ambient PM2.5	Cost	OECD

An increase in some variables and a decrease in others indicates a positive situation. If the increase in the value of the variable indicates a positive situation, it is evaluated according to the benefit criterion; if the decrease in the value of the variable indicates a positive situation, it is evaluated within the cost criterion

3.3 Creation of indices for BRICS-T countries

It has been revealed that Turkey can now become a member of the BRICS country group (Brazil, Russia, India, China and South Africa), which is a rapidly growing and developing country group, considering the recent developments. The reason why BRICS-T countries, which were created by including the Turkish economy in this group, are the subject of the study is that both their economic and environmental impacts will have great importance on a global scale during the development process. With a population of over 3 billion, more than 25% of the world economy and approximately 27% of the world's land, this country group's performance in terms of sustainable development is of great importance on a global scale. Therefore, it was determined as the investigation area of the research (https://www.bbc.com).

The reason for including Turkey in this group is due to its similarity in land area to the other group countries, its comparable economy, its recent efforts towards rapid growth and development, and Turkey's significance in recent global developments (especially the Ukraine-Russia war). Additionally, the famous British economist Jim O'Neill mentioned in an interview with Anadolu Agency that Turkey could be included in the expanding BRICS group, which is why it was deemed appropriate to add Turkey to the BRICS country group (https://www.aa.com.tr).

To create an index for BRICS-T countries, the data of the variables shown in Table 1 for the period 1990–2022 were used. With the help of the formulas mentioned above, indexes were first created for three different groups. The graphs of three different indices created for the countries in the sample are given in the subheadings[1].

3.3.1 Economic index

Before analyzing the SDI, it is useful to first display the subcategories of economic index, environmental index, and outcome index values on a graph. These values have been calculated by the author. The economic index is one of the three main subcategories of the SDI. In calculating the index, the current account balance, FDI, total reserves, GDP per capita, and unemployment rate data used by the OECD in its SDI calculations were utilized (Hass et al., 2003). The results of the economic index, as shown in Fig. 1, exhibit similar trends across countries.

Brazil's economic performance was generally stable in the 1990s. In the early 2000s, it experienced a decline, but saw a recovery after 2010, peaking around 2014. In recent years, fluctuations have continued. China has shown a continuous upward trend since the late 1990s. However, a noticeable decline in economic performance began after 2015, reaching its lowest point in 2021. There are several possible reasons for the low economic indicators in China. Firstly, China's rapid economic growth has largely been driven by low value-added production and high environmental costs. This situation has arisen as a result of rapid industrialization carried out without adequate measures for environmental sustainability and quality. Additionally, income distribution inequalities and economic disparities between regions in China negatively affect overall economic indicators. The low income levels of the rural population, in particular, drag down the country's overall economic performance. Furthermore, environmental degradation and pollution costs play a significant role in China's

[1] Index calculation results are shown as a table in the Appendices.

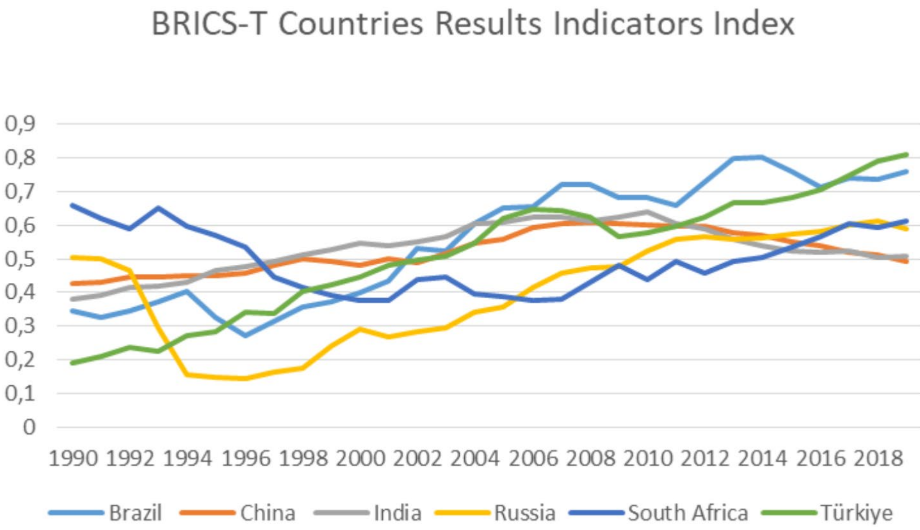


Fig. 1 BRICS-T Countries Economic Index

economic data. Therefore, the low economic indicators within the sustainable development index can be seen as a combination of these factors.

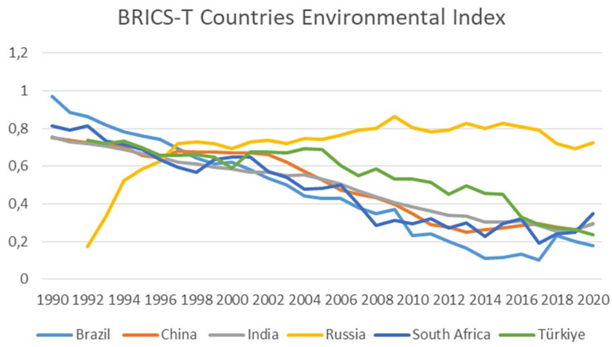
Since the early 1990s, India has generally shown stable economic performance. After 2010, a significant upward trend was observed, peaking in 2020, followed by a decline. Russia experienced a major economic crisis in the late 1990s, hitting rock bottom in 1998. The economy recovered in the 2000s, faced another dip in 2008, and then followed a relatively stable path after 2010. Another downturn occurred in 2020. South Africa's economic performance has been volatile since the early 1990s. Increases were seen in the early 2000s and around 2010, but overall, there have been significant fluctuations. A sharp increase was observed in 2020, followed by a decline. Turkey has exhibited a fluctuating economic performance since the early 1990s. It experienced a significant downturn during the 2001 crisis, recovered in the mid-2000s, and showed further fluctuations after 2010. In 2020, a sudden increase was followed by a decline.

Many countries experienced recovery and growth in economic indicators in the early 2000s, a period marked by accelerated global economic expansion. The global financial crisis of 2008 resulted in downturns in economic indicators for many countries. In 2020, sudden increases followed by declines are observed across all countries, reflecting the impact of the COVID-19 pandemic on economic indicators. Economic performance significantly influences the overall sustainability level of countries as a critical component of sustainable development. Therefore, careful examination and understanding of fluctuations in economic indicators are important.

3.3.2 Environmental index

According to Fig. 2, based on the index values derived from the environmental indicators of BRICS-T countries, Brazil's environmental performance started at high levels in the early 1990s but has consistently trended downward over the years. Despite some fluctuations in

Fig. 2 BRICS-T Countries Environmental Index



performance during the 2010s, the overall trend has continued to decline. This trend can be associated with Brazil's increasing deforestation rates and inadequacies in environmental management policies.

China's environmental indicators have shown a continuous decline since the 1990s. Although there was a brief recovery in the early 2000s, the overall trend has been downward. This situation stems from China's rapid industrialization and urbanization processes, leading to increasing environmental pollution issues.

India's environmental performance has exhibited a gradual decline since the 1990s. However, compared to other countries, the downward trend has been relatively moderate. Among India's environmental issues are factors such as water pollution, air pollution, and decreasing biodiversity.

Russia's environmental indicators started at low levels in the early 1990s and showed a gradual increase until the 2000s. However, since 2010, a declining trend has been observed, although they remain significantly higher compared to other BRICS-T countries. There are several reasons why Russia's environmental indicators may be higher than those of other BRICS-T countries. Firstly, Russia has extensive forested areas that contribute significantly to carbon dioxide absorption and biological diversity, thereby positively impacting environmental indicators. Secondly, Russia's vast land area and low population density result in less environmental pressure compared to other countries, thereby enhancing environmental sustainability and improving environmental indicators. Thirdly, in recent years, Russia has strengthened its environmental policies and regulations. These policies have increased environmental protection measures and contributed to the improvement of environmental indicators.

South Africa's environmental performance has generally followed a declining trend since the early 1990s. Although there were some signs of recovery in the 2000s, the decline has continued since 2010. This trend can be attributed to South Africa's mining activities and weaknesses in environmental regulations.

Turkey's environmental indicators have fluctuated since the 1990s, but the overall trend has been downward. While there was some improvement in performance after 2015, this increase was not sustained. Among Turkey's environmental issues are factors such as air pollution, declining water resources, and deforestation.

The graph shows a general decline in environmental performance across all countries. This trend can be associated with increasing global environmental issues and inadequate measures taken to address them. The data in the graph clearly indicate the need for more improvements in the environmental components of sustainable development efforts. Countries should strengthen their environmental management policies and develop long-term strategies to achieve sustainable development goals. In this context, international cooperation and sharing of knowledge also hold critical importance.

3.3.3 Results indicators index

According to Fig. 3, which shows the results of the composite index based on outcome indicators, Brazil's performance started at moderate levels in the early 1990s and followed a fluctuating trend until the mid-1990s. From the 2000s onwards, there has been a general upward trend in performance. This increase can be associated with improvements in social indicators such as access to education, healthcare services, and expansion of social welfare programs.

China's social indicators have shown a continuous increase since the 1990s. This upward trend became more pronounced after 2010. This can be attributed to increased investments in social development alongside China's economic growth, leading to improvements in living standards.

Since the beginning of the 1990s, India has shown a gradual increase and demonstrated stable performance in the early 2000s. This upward trend has continued after 2010 as well. Reforms in health, education, and poverty alleviation in India have supported this improvement.

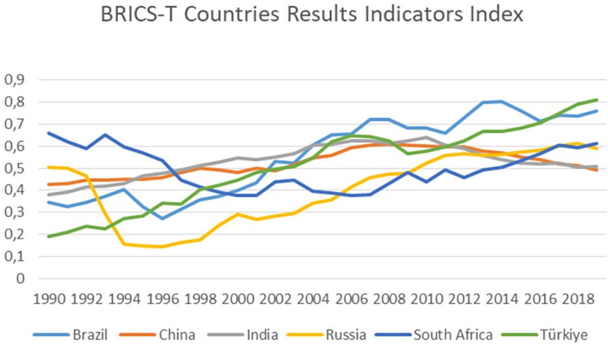
Russia's social performance declined in the early 1990s but experienced gradual recovery throughout the 2000s. A more pronounced upward trend has been observed since 2010. This recovery can be attributed to Russia's strengthening of social policies following the economic crisis and efforts to increase welfare levels.

South Africa's social indicators started at low levels in the early 1990s and showed a decline until the late 1990s. From the 2000s onwards, there has been an upward trend, which became more pronounced after 2010. This increase can be attributed to the social reforms implemented in the post-apartheid era and efforts to combat inequality.

Turkey's social performance has shown a continuous upward trend since the beginning of the 1990s. Particularly after the 2000s, a significant increase has been observed. Reforms in healthcare, education, and social security in Turkey have supported this improvement.

A general increase in social performance is observed for all countries in the graph. This trend reflects the impact of investments and reforms in social development. The improvements in social indicators are a direct reflection of countries' investments in education,

Fig. 3 BRICS-T Countries Results Indicators Index



healthcare, and social security policies. The data in the graph clearly indicate significant progress in the social components of sustainable development efforts. Countries should continue to strengthen their social policies and develop long-term strategies aimed at increasing societal well-being to achieve sustainable development goals. In this context, international cooperation and knowledge sharing also play a critical role in achieving social development objectives.

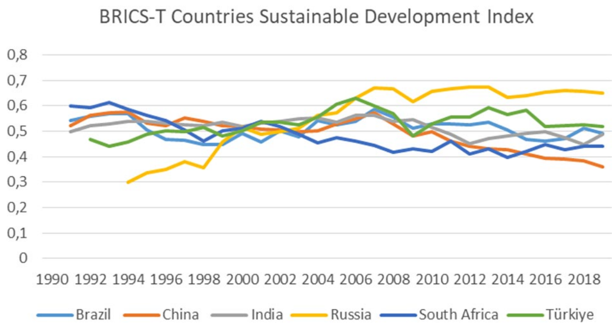
The Sustainable Development Index, which is created by taking the average of the indexes in these three groups, is calculated with the assumption that economic, environmental and result indicators affect the same rate. Due to some deficiencies in the first years of the variables used, Russia's index value was calculated for after 1994, while Turkey's index value could be calculated for after 1992.

3.3.4 Sustainable development index

The SDI values for BRICS-T countries are shown in Fig. 4. This index is constructed by weighting economic, environmental, and social indicators, reflecting countries' sustainable development performances. The index values in the graph range between 0 and 1, where higher values indicate better sustainable development performance. In the early 1990s, countries' SDI values generally remained at average levels. This period did not show significant fluctuations, with index values ranging between 0.4 and 0.6 for most countries. In the early 2000s, significant fluctuations and declines were observed in some countries, which may reflect the impact of global economic crises and transitional periods. From 2010 onwards, a general trend of recovery and stability is observed. During this period, many countries made progress in economic and social indicators and embarked on efforts to improve their environmental performance. There are significant differences in sustainable development performance among countries. While some countries show a continuous upward trend in the SDI, others follow a more volatile trajectory. In the post-2010 period, there is a general increase and stability in countries' SDI values. This trend can be explained by the effective implementation of sustainable development policies and increased international cooperation.

Brazil's sustainable development index remained at an average level (between 0.4 and 0.6) in the 1990s. There was a significant decline in the early 2000s, but a recovery trend has been observed since 2010. This trend indicates that Brazil's advancements in social and economic indicators have balanced out weaknesses in its environmental performance. These findings are consistent with the literature (Frontiers, 2020), which has highlighted Brazil's weak environmental performance.

Fig. 4 BRICS-T Countries Sustainable Development Index



China's sustainable development index has shown a continuous upward trend since the 1990s. However, there has been a significant decline since 2015. This situation is associated with China's rapid economic growth and social development investments being able to compensate for environmental degradation, but it is increasingly linked to rising environmental issues in recent years. China's performance is consistent with the economic growth and advancements in social development areas noted by Wu and Wu (2012). However, the decline after 2015 coincides with the increase in environmental problems.

India has generally shown an upward trend since the early 1990s and exhibited stable performance in the mid-2000s. India's efforts in economic and social development have supported environmental sustainability. The sustainable development index for India in the graph indicates that despite environmental challenges, economic and social advancements have generally supported an upward trend. These findings are consistent with those in the literature (Bhattacharya & Dasgupta, 2019).

Russia's sustainable development index declined in the late 1990s but began to recover in the 2000s. Since 2010, a more stable performance has been observed. This recovery is associated with Russia strengthening its social and economic policies following the economic crisis. The upward trend in Russia's performance during the 2000s, as shown in the graph, is consistent with findings in the literature (Sustainable Development in BRICS Countries, 2018), which highlight the alignment with strengthened economic and social policies.

South Africa's sustainable development index started at low levels in the early 1990s and declined until the 2000s. Since the 2000s, there has been a significant increase in its performance. This improvement can be attributed to social reforms implemented in the post-apartheid era and efforts to combat inequality. The increased sustainable development performance of South Africa from the 2000s onward, as depicted in the graph, aligns with the literature on social reforms and efforts to combat inequality (Sustainable Development Goal Interactions, 2021).

Turkey's sustainable development index has shown a continuous upward trend since the early 1990s. A significant increase has been observed since the 2000s. Reforms in healthcare, education, and social security in Turkey have positively influenced its sustainable development performance. The increasing sustainable development performance of Turkey, as depicted in the graph, is consistent with the findings of Şahin and Kula (2015) on economic and social reforms. The deficiencies in environmental indicators have not fully negatively impacted the overall performance.

4 Econometric application

In this part of the study, econometric analysis will be applied to the panel data set of BRICS-T countries for the period 1996–2019 in order to test the applicability of the index created above. Information about the variables used in the panel data set is given in Table 2.

The dependent variable used in the study is SDI values, while the independent variables consist of R&D expenditures, external debt stock and the amount of renewable energy consumption. Since it constitutes the main subject of the study, SDI has been determined as the dependent variable. R&D expenditures will bring technological development. There are many studies in the literature that this development increases environmental pollution, especially in developing countries. Therefore, since the countries that are the subject of the

Table 2 Information on variables

Variable	Definition	Source
I	The index defined above	Calculated by authors
A	Research and development expenditure (% of GDP)	World Bank
B	External debt stocks (% of GNP)	World Bank
Y	Renewable energy consumption (% of total final energy consumption)	World Bank

Table 3 Breusch-Pagan LM test results

	Test	Statistics	s.d.	possibility
I	Breusch-Pagan LM	87.52058*	15	0.0000
A	Breusch-Pagan LM	61.22892*	15	0.0000
B	Breusch-Pagan LM	41.58606*	15	0.0003
Y	Breusch-Pagan LM	180.0935*	15	0.0000

Note: * Denotes significance at 1% level

study are developing countries, the effect of the increase in the level of development on sustainable development is important.

The reason for using external debt stock data, which is another independent variable, is to determine the impact of countries' indebtedness level on development. The last independent variable is the ratio of renewable energy consumption. The reason for choosing this variable is to reveal how effective it is in reducing environmental pollution, which is extremely important for the goal of sustainability.

4.1 Stationarity test

Since the analyses used in econometric models are sensitive to the degree of stationarity of the variables, stationarity should be examined before starting the study (Karadaş, 2020). There are many tests to examine stationarity in panel data analyses. These tests are divided into two categories depending on the assumption whether the series contain cross-section dependence or not. While the first generation unit root tests assume that there is no cross-sectional dependence, the second generation unit root tests assume that there is cross-sectional dependence (Karadaş, 2021). Therefore, first of all, the cross-section dependence of the series should be examined. Cross-section dependence tests are sensitive to time and cross-section size. Since the cross-sectional dimension ($N=6$) in the study is larger than the time dimension (T = 28), the Breusch-Pagan LM test should be used.

As seen in Table 3, there is cross-sectional dependence in the series used according to the Breusch-Pagan LM Test. For this reason, the CIPS test, the second-generation unit root test most used in the literature, was used to examine stationarity. As a result of the unit root test, it is seen that variable B is stationary at level while variables I, A and Y are stationary at first order. Table 4.

4.2 Panel ARDL test

As with time series analysis, there are many cointegration tests in the literature for panel data analysis. Some of these are panel cointegration tests such as Panel ECT, Pedroni, Kao,

Table 4 Unit Root Test results

	Without trend		With trend	
Variable	Zt-bar	*p*-value	Zt-bar	*p*-value
I	-0.467	0.320	-1.221	0.111
D.I	-4.405*	0.000	-2.467*	0.007
A	-0.141	0.444	0.309	0.621
D.A	-3.042*	0.001	-1.900**	0.029
B	-2.791*	0.003	-2.758*	0.003
Y	0.389	0.651	3.181	0.999
D.Y	-1.631***	0.051	-1.984**	0.024

Note: *, ** and *** denotes significance at %1, %5 and %10 level, respectively

Fisher, error correction based Westerlund and panel ARDL (AutoRegressive Distrubuted Lag). While panel ECT is used for stationary series at level, Pedroni, Kao and Fisher panel co-integration tests are used for stationary series at first order. The panel ARDL co-integration test is used to examine the relationship between series of different degrees according to the PMG (Pooled Mean Group) and MG (Mean Group) estimators (Özbek, 2023). Briefly, some of the series used in the panel ARDL test may be I(0) while others may be I(1). Since the variables are stationary at different levels according to the unit root test results in the previous section, it was decided to apply the panel ARDL cointegration test.

Pesaran and Smith (1995) and Pesaran et al. (1999), propose two different estimators, MG and PMG, to counter the heterogeneity problem encountered in dynamic panels. MG assumes that there is no commonality between the units in the panel. PMG accepts that the long-term coefficients for the units in the panel are the same, but the short-term coefficients are different. The fact that there are two different estimators with different assumptions makes it necessary to choose the effective one among these two. According to the assumptions of these two estimators, it can be said that if there is a homogeneous relationship between the units in the panel, the MG estimator is more effective, and if there is a non-homogeneous relationship between the units, the PMG estimator is more effective (Pesaran et al., 1999). As can be seen from here, the short- and long-term coefficients of the variables obtained with the MG estimator are different for the panel sections. While the short-term coefficients obtained with the PMG estimator are different, the long-term coefficients are the same.

To determine which of these two estimators is more effective, the homogeneity of the series can be examined or the panel ARDL-based Hausman test can be applied. In this study, the Hausman test was preferred instead of examining the homogeneity of the series. While comparing these two estimators, the Hausman test examines the null hypothesis of the Hausman test according to the chi-square value found. Accordingly, it accepts that the initial estimator (b) is consistent according to both the null hypothesis (H_0) and the alternative hypothesis (H_a). It is appropriate that the second ranked estimator (B) is inconsistent under Ha and effective under H_0 (Mehmood et al., 2014). Hausman test results applied to the model in the study are given in Table 5.

As a result of the Hausman test applied to the MG and PMG estimators, the null hypothesis could not be rejected and it was seen that the second ranked PMG test of these two estimators was consistent. The long-term coefficients of the panel ARDL test applied according to the PMG test are given in Table 6.

The ARDL model results reveal the relationships between the Sustainable Development Index (I) and Research and Development Expenditures (A), External Debt Stock (B), and

Table 5 Hausman Test for MG and PMG estimators

	(b)	(B)	(b-B)	Sqrt (diag(V_b-V_B))
	MG	PMG	Difference	S.E.
A	-0.0759151	-0.0932168	0.0173017	0.0735133
B	0.0013493	-0.0005732	0.0019225	0.0034578
Y	0.0246341	0.0059342	0.0186999	0.0339697
$chi^2(4)$ = (b-B)'[(V_b-V_B)^(-1)](b-B) = 0.44				
Prob > chi2 = **0.9313**				

Table 6 Panel ARDL long-term coefficients according to PMG Estimator

Dependent variable: I						
	Coefficient	Standard error	z	P>|z|	95% confidence interval	
ECT	-0.4518183*	0.1572257	-2.87	0.004	-0.759975	-0.1436616
A	-0.0932168**	0.0466482	-2.00	0.046	-0.1846456	-0.0017879
B	-0.0005732	0.0004875	-1.18	0.240	-0.0015288	0.0003823
Y	0.0059342*	0.0015268	3.89	0.000	0.0029417	0.0089267

Note: * and ** denotes significance at %1 and %5 level, respectively

Renewable Energy Consumption (Y). According to the model results, the error correction term (ECT) has a coefficient of -0.4518, which is negative and statistically significant ($p<0.05$). This indicates that the long-term coefficients are valid and interpretable. Specifically, the negative sign of the coefficient suggests that approximately 45% of deviations from long-term equilibrium in the Sustainable Development Index are corrected within one period. In other words, deviations from equilibrium are corrected by about 45% within one period. Moreover, the coefficient being in the range of (-1,0) indicates that if a deviation occurs from equilibrium, it would take approximately 2 periods ($2 \cong 1/0.45$) to return to the equilibrium point. As mentioned earlier, the PMG estimator assumes that short-term coefficients differ across cross-sections.

When examining the significance of the long-term coefficients given in Table 6, a negative and significant relationship has been identified between Research and Development Expenditures (A) and the Sustainable Development Index ($p<0.05$). The coefficient value is -0.0932, indicating that a one-unit increase in Research and Development Expenditures leads to approximately a 0.093 unit decrease in the Sustainable Development Index. This finding suggests that Research and Development Expenditures have a negative impact on sustainable development. The negative effect of Research and Development Expenditures on the Sustainable Development Index is noteworthy and contrary to the hypothesis. This indicates that in developing countries, Research and Development expenditures could lead to environmentally unfriendly technological developments, thereby adversely affecting sustainable development. While developed countries have stringent environmental regulations, developing countries may have more relaxed regulations, potentially facilitating the spread of environmentally harmful innovations.

Renewable energy consumption (Y) has a positive and significant effect ($p<0.01$). The coefficient is 0.0059, indicating that a one-unit increase in renewable energy consumption leads to approximately a 0.0059 unit increase in the Sustainable Development Index. This finding suggests that renewable energy consumption has a positive impact on sustainable development. The positive and statistically significant effect of renewable energy consumption underscores its crucial role in achieving sustainable development goals. Increasing renewable energy sources positively influences the Sustainable Development Index by reducing adverse environmental impacts. This result is consistent with the hypothesis and existing literature.

The coefficient obtained for external debt stock (B) is -0.0006, and it is not statistically significant ($p > 0.05$). This result indicates that external debt stock does not have a significant impact on the Sustainable Development Index (SDI). This finding suggests that in BRICS-T countries, external debt stock does not exert a substantial influence on sustainable development. Our hypothesis expected a negative relationship between SDI and external debt stock, which contrasts with the literature. This finding suggests that the impact of external debt on sustainable development is complex and may depend on country-specific factors.

To mitigate the adverse effects of R&D expenditures on sustainable development in developing countries, more investment should be directed towards environmentally friendly technologies and sustainable innovations. Environmentally sensitive R&D projects should be encouraged, and innovations that minimize environmental impacts should be supported. Given the positive impact of renewable energy consumption on sustainable development, policies should be developed to increase the use of these energy sources. Investments in renewable energy should be incentivized, and technological developments in this field should be supported. While the impact of external debt on sustainable development may not be significant, debt management policies should align with long-term sustainable development goals. External borrowing should be structured to support economic growth while ensuring environmental sustainability is considered.

This study makes a significant contribution to the literature by analyzing the relationships between the Sustainable Development Index and specific economic and environmental variables for BRICS-T countries. Future research could examine how these relationships vary with country-specific factors and conduct more comprehensive analyses using a broader dataset. Additionally, case studies and applied research on how policymakers can implement these findings would provide valuable contributions to the literature.

5 Conclusion

Sustainable development is increasingly expressed as a desirable path in society. The basic basis for this is to comply with the Sustainable Development Goals. Therefore, adapting the policies of BRICS-T countries to the 2030 Agenda and measuring it is a necessary issue in order to progress towards achieving the Sustainable Development Goals.

In the study, sustainable development index values of BRICS-T countries were compiled from OECD data. The sustainable development index is monitored under three subheadings: economic, environmental and result indicators. While the trend followed by the countries in terms of economic index for BRICS-T countries shows very similar values, China's index value has decreased slightly compared to other countries in recent years.

It is seen that Russia differs from other countries in terms of environmental index and follows a positive trend, while the index values of other countries have followed a negative trend until the last few years. When compared in terms of result indicators, it is seen that the countries have very similar trends and follow a positive course. Although the countries show similar results and follow a horizontal course in terms of sustainable development index, it is seen that Russia has left other countries positively since 2005, while China has left negative since 2007.

In the final section of the study, the long-term relationship between the Sustainable Development Index (SDI) of BRICS-T countries and external debt stock, R&D expenditures, and renewable energy consumption was analyzed using the Panel ARDL method with data from 1996 to 2019. The analysis reveals significant findings regarding the relationships between SDI and R&D expenditures, renewable energy consumption, and external debt stock in BRICS-T countries. The results indicate that R&D expenditures negatively affect the sustainable development index, while renewable energy consumption has a positive impact. These findings provide important implications for shaping public policies in BRICS-T countries towards sustainable development goals.

The finding that R&D expenditures negatively affect the sustainable development index is attributed to these expenditures being directed towards non-environmentally friendly technological developments. This situation necessitates a review of R&D policies in BRICS-T countries. It is emphasized that more investment should be made in R&D projects that minimize environmental impacts and promote sustainable innovations. This approach will facilitate achieving sustainable development goals through the development and dissemination of eco-friendly technologies. Policymakers can develop stricter regulations and incentive mechanisms by considering environmental sustainability in directing R&D investments. For instance, tax incentives, direct subsidies, and low-interest loans can be provided for eco-friendly technologies. Furthermore, regulations and restrictions on projects that disregard environmental impacts should be strengthened.

The positive impact of renewable energy consumption on the sustainable development index underscores the importance of increasing the use of these energy sources. BRICS-T countries should strengthen incentive policies towards renewable energy sources and support technology development in this area. Increasing investments in renewable energy will be a significant step towards environmental sustainability. Renewable energy policies should be integrated harmoniously with long-term sustainable development strategies, and investments in this area should be encouraged. Governments should increase infrastructure investments to promote renewable energy projects and facilitate access to renewable energy technologies. Additionally, public awareness campaigns should be organized to promote renewable energy use, and policies that encourage renewable energy consumption should be implemented.

The lack of a significant relationship between external debt stock and the sustainable development index indicates the need for further research in this area. Debt management policies should be aligned with sustainable development goals and support long-term sustainable development strategies. In this context, it is crucial that debt is structured to support economic growth while also considering environmental sustainability. Debt policies should be designed to consider not only economic growth but also environmental and social sustainability. Governments should integrate sustainable development goals into their debt management policies. Strategies for debt usage should be developed to minimize environmental and social impacts, and these strategies should be harmonized with sustainable development objectives.

The study has certain limitations. The dataset used is limited to a specific time period, and some variables were excluded from the analysis due to missing data. Future research could overcome these limitations by using larger and more up-to-date datasets to conduct more comprehensive analyses. Additionally, conducting detailed case studies to examine the impact of country-specific factors on sustainable development is recommended. In this context, more detailed studies can be conducted taking into account the unique economic, social, and environmental dynamics of each BRICS-T country. These studies will demonstrate how sustainable development strategies can be adapted to meet country-specific needs and conditions.

As a result, this study provides significant contributions to sustainable development policies for BRICS-T countries. Increasing the use of renewable energy and promoting eco-friendly R&D projects are crucial in achieving sustainable development goals. These findings highlight important considerations that policymakers need to take into account when shaping sustainable development strategies. BRICS-T countries need to develop innovative and integrated policies focusing on environmental sustainability to achieve sustainable development goals. These policies should meet the needs of current generations while preserving resources for future generations, advancing towards sustainable development.

Appendices

Appendix 1 Economic Index

	Brazil	China	India	Russia	South Africa	Turkey
1990						
1991	0.415916	0.403941	0.370455		0.381706	0.400731
1992	0.472788	0.514751	0.430176		0.375456	0.427887
1993	0.512482	0.557688	0.456539		0.449066	0.381494
1994	0.523859	0.582692	0.493802	0.223981	0.449864	0.364065
1995	0.422287	0.48332	0.48039	0.271158	0.432593	0.480248
1996	0.394636	0.460075	0.474336	0.281852	0.454033	0.502828
1997	0.382892	0.49298	0.462941	0.26052	0.471192	0.503408
1998	0.33795	0.446453	0.439122	0.168944	0.396631	0.480122
1999	0.355546	0.400446	0.484841	0.420868	0.474638	0.37935
2000	0.45747	0.40152	0.425236	0.557348	0.510171	0.468775
2001	0.359864	0.356618	0.486432	0.474765	0.592806	0.447909
2002	0.436949	0.363179	0.503705	0.474964	0.537174	0.431389
2003	0.415176	0.358032	0.533726	0.521564	0.477282	0.39732
2004	0.586871	0.392092	0.502347	0.595198	0.488842	0.425132
2005	0.493786	0.499649	0.460533	0.615683	0.55734	0.512361
2006	0.535357	0.582777	0.557715	0.706631	0.512454	0.633328
2007	0.652373	0.659538	0.596153	0.76117	0.551821	0.609575
2008	0.599595	0.546637	0.56669	0.726566	0.535202	0.500576
2009	0.478906	0.443382	0.602937	0.506556	0.501611	0.3459
2010	0.666933	0.54428	0.523098	0.636786	0.533858	0.481224
2011	0.689225	0.495807	0.502863	0.65903	0.57036	0.555591
2012	0.652	0.446847	0.42339	0.664089	0.500562	0.592638
2013	0.642803	0.461931	0.523083	0.639356	0.499046	0.61823
2014	0.605484	0.448322	0.59952	0.539196	0.465564	0.569153
2015	0.525645	0.407835	0.651043	0.521539	0.428654	0.611618
2016	0.53723	0.35622	0.669263	0.57265	0.460267	0.519583

Appendix 1 Economic Index

	Brazil	China	India	Russia	South Africa	Turkey
2017	0.567234	0.360652	0.620113	0.5901	0.493607	0.529533
2018	0.563618	0.360041	0.589007	0.633639	0.487363	0.51431
2019	0.514335	0.326262	0.693128	0.672845	0.460628	0.48612
2020	0.406473	0.269534	0.510549	0.566915	0.469827	0.376844
2021	0.538636	0.429105	0.734539	0.764214	0.798027	0.638984
2022	0.66009	0.27399	0.669551		0.499441	0.558614

Appendix 2 Environmental Index

	Brazil	China	India	Russia	South Africa	Turkey
1990	0.96955	0.75	0.754477		0.812651	
1991	0.887274	0.736829	0.729597		0.792694	
1992	0.864742	0.726069	0.71951	0.175725	0.816296	0.739187
1993	0.81995	0.715317	0.706141	0.332975	0.73536	0.719297
1994	0.78371	0.701763	0.689183	0.523838	0.714922	0.735246
1995	0.76219	0.657149	0.666432	0.587648	0.687159	0.698509
1996	0.741117	0.644771	0.647628	0.627478	0.635795	0.659645
1997	0.695573	0.677903	0.623916	0.718695	0.596038	0.657537
1998	0.646158	0.67446	0.612042	0.728377	0.569592	0.662297
1999	0.613177	0.676729	0.593204	0.718527	0.633985	0.648658
2000	0.62039	0.669609	0.584394	0.692418	0.649858	0.590779
2001	0.581268	0.672962	0.570095	0.72731	0.650166	0.674609
2002	0.534663	0.660247	0.567579	0.740174	0.574355	0.674169
2003	0.499473	0.623683	0.548623	0.718421	0.541588	0.670423
2004	0.441629	0.570775	0.553098	0.747751	0.476261	0.695308
2005	0.428317	0.529065	0.531137	0.742179	0.484244	0.688269
2006	0.427363	0.475932	0.506446	0.76531	0.500849	0.605824
2007	0.381154	0.451566	0.470209	0.790996	0.399441	0.548868
2008	0.346248	0.432293	0.438495	0.798822	0.285781	0.583823
2009	0.370762	0.397691	0.406929	0.865205	0.313837	0.533417
2010	0.233906	0.347048	0.382088	0.806571	0.293995	0.530791
2011	0.242739	0.291139	0.359754	0.784481	0.319444	0.515908
2012	0.199168	0.277088	0.338702	0.793649	0.270799	0.453384
2013	0.164095	0.25069	0.333211	0.828143	0.298731	0.494743
2014	0.109281	0.261549	0.301357	0.800757	0.225463	0.45702
2015	0.116101	0.27274	0.303373	0.82778	0.295957	0.450928
2016	0.133773	0.28598	0.308857	0.807765	0.319873	0.332624
2017	0.104142	0.292472	0.28598	0.789942	0.18967	0.289371
2018	0.232252	0.276567	0.252242	0.721906	0.242771	0.274359
2019	0.202473	0.264556	0.262526	0.691202	0.250755	0.261951
2020	0.180351	0.294772	0.292846	0.723887	0.346604	0.238138

Appendix 3 Results Indicators Index

	Brazil	China	India	Russia	South Africa	Turkey
1990	0.345422	0.428571	0.381381	0.505999	0.657978	0.189866
1991	0.327634	0.429659	0.3917	0.498895	0.621833	0.209896
1992	0.344866	0.445447	0.41372	0.466419	0.588894	0.238162

Appendix 3 Results Indicators Index

	Brazil	China	India	Russia	South Africa	Turkey
1993	0.370892	0.447713	0.418916	0.293756	0.651322	0.224423
1994	0.402288	0.448252	0.430556	0.155168	0.596974	0.273692
1995	0.327476	0.451757	0.465234	0.149329	0.568932	0.283816
1996	0.270864	0.457983	0.476656	0.144768	0.53399	0.340586
1997	0.316346	0.48191	0.493912	0.164156	0.446112	0.338272
1998	0.356138	0.498834	0.510281	0.174706	0.41505	0.402839
1999	0.370764	0.491039	0.528136	0.239254	0.392464	0.421918
2000	0.398953	0.480366	0.54888	0.292925	0.377445	0.444629
2001	0.434012	0.499452	0.540002	0.268028	0.376495	0.479659
2002	0.532991	0.490697	0.550663	0.284077	0.44025	0.49845
2003	0.524123	0.517252	0.567495	0.296955	0.445533	0.508922
2004	0.60335	0.546025	0.605497	0.340121	0.39438	0.546099
2005	0.650163	0.559497	0.610498	0.358183	0.387786	0.619403
2006	0.655326	0.591664	0.623928	0.413839	0.375395	0.646503
2007	0.722497	0.605289	0.626412	0.457397	0.381386	0.644883
2008	0.720031	0.609538	0.613477	0.472044	0.429662	0.624842
2009	0.68139	0.604374	0.62575	0.475684	0.481992	0.567286
2010	0.683581	0.600784	0.640926	0.522842	0.436884	0.578744
2011	0.657944	0.59603	0.605489	0.558147	0.49352	0.59598
2012	0.727934	0.598835	0.588086	0.568047	0.457114	0.623987
2013	0.800792	0.576935	0.557869	0.558685	0.49287	0.665587
2014	0.804538	0.56957	0.539423	0.561313	0.503868	0.666993
2015	0.759416	0.552501	0.523945	0.575182	0.536956	0.682954
2016	0.712256	0.539056	0.520165	0.583775	0.568117	0.707306
2017	0.739734	0.520408	0.522911	0.600189	0.603445	0.747358
2018	0.737658	0.512889	0.502682	0.612011	0.593643	0.790741
2019	0.758353	0.492193	0.510037	0.588304	0.612949	0.81074

Appendix 4 Sustainable Development Index

	Brazil	China	India	Russia	South Africa	Turkey
1990						
1991	0.543608	0.523476	0.497251		0.598745	
1992	0.560799	0.562089	0.521135		0.593549	0.468412
1993	0.567774	0.573572	0.527199		0.611916	0.441738
1994	0.569953	0.577569	0.537847	0.300996	0.587254	0.457667
1995	0.503984	0.530742	0.537352	0.336045	0.562895	0.487524
1996	0.468872	0.520943	0.532873	0.351366	0.541273	0.50102
1997	0.464937	0.550931	0.526923	0.381124	0.504447	0.499739
1998	0.446749	0.539916	0.520482	0.357342	0.460424	0.515086
1999	0.446496	0.522738	0.535394	0.45955	0.500362	0.483309
2000	0.492271	0.517165	0.519503	0.51423	0.512491	0.501394
2001	0.458382	0.509677	0.532176	0.490035	0.539823	0.534059
2002	0.501534	0.504708	0.540649	0.499738	0.51726	0.53467
2003	0.47959	0.499656	0.549948	0.512314	0.488134	0.525555
2004	0.54395	0.502964	0.553647	0.561023	0.453161	0.555513
2005	0.524089	0.529404	0.534056	0.572015	0.476456	0.606677
2006	0.539348	0.550124	0.562696	0.628594	0.462899	0.628552

Appendix 4 Sustainable Development Index

	Brazil	China	India	Russia	South Africa	Turkey
2007	0.585341	0.572131	0.564258	0.669854	0.444216	0.601109
2008	0.555291	0.529489	0.539554	0.665811	0.416882	0.569747
2009	0.510353	0.481816	0.545205	0.615815	0.43248	0.482201
2010	0.52814	0.497371	0.515371	0.6554	0.421579	0.530253
2011	0.529969	0.460992	0.489369	0.667219	0.461108	0.555826
2012	0.526367	0.440923	0.450059	0.675261	0.409492	0.556669
2013	0.535896	0.429852	0.471388	0.675395	0.430216	0.592854
2014	0.506434	0.426481	0.4801	0.633755	0.398299	0.564389
2015	0.467054	0.411025	0.492787	0.641501	0.420522	0.581833
2016	0.461087	0.393752	0.499428	0.65473	0.449419	0.519838
2017	0.47037	0.391178	0.476335	0.660077	0.428907	0.522087
2018	0.511176	0.383166	0.447977	0.655852	0.441259	0.52647
2019	0.49172	0.361004	0.488564	0.650784	0.441444	0.519603

Appendix 5 Short-term coefficients by country

Dependent variable: LS

	Coefficient	Standard Error	z	P>|z|	95% confidence interval	
A	-0.0932168	0.0466482	-2.00	0.046	-0.1846456	-0.0017879
B	-0.0005732	0.0004875	-1.18	0.240	-0.0015288	0.0003823
Y	0.0059342	0.0015268	3.89	0.000	0.0029417	0.0089267
Brazil						
ECT	-0.9799171	0.2078024	-4.72	0.000	-1.387202	-0.572632
A	0.2263119	0.093187	2.43	0.015	0.0436687	0.4089551
B	-0.0008955	0.0012397	-0.72	0.470	-0.0033253	0.0015343
Y	-0.0079214	0.0038263	-2.07	0.038	-0.0154209	-0.000422
C	0.3562247	0.1253097	2.84	0.004	0.1106222	0.6018272
China						
ECT	-0.0976118	0.0593141	-1.65	0.100	-0.2138654	0.0186417
A	-0.1663516	0.0667461	-2.49	0.013	-0.2971716	-0.0355317
B	0.0012437	0.0019753	0.63	0.529	-0.0026278	0.0051151
Y	-0.006367	0.0028592	-2.23	0.026	-0.0119709	-0.000763
C	0.0519454	0.0303865	1.71	0.087	-0.0076112	0.1115019
India						
ECT	-0.4462593	0.1652348	-2.70	0.007	-0.7701135	-0.1224051
A	-0.1953043	0.1141396	-1.71	0.087	-0.4190139	0.0284053
B	-0.0004395	0.0023214	-0.19	0.850	-0.0049892	0.0041103
Y	-0.0128443	0.0066318	-1.94	0.053	-0.0258424	0.0001539
C	0.148766	0.078392	1.90	0.058	-0.0048796	0.3024116
Russia						
ECT	-0.1765422	0.0582861	-3.03	0.002	-0.2907809	-0.0623036
A	-0.1267133	0.069393	-1.83	0.068	-0.2627211	0.0092945
B	-0.0006664	0.0004567	-1.46	0.145	-0.0015616	0.0002288
Y	0.0418153	0.0299004	1.40	0.162	-0.0167884	0.100419
C	0.1337418	0.042069	3.18	0.001	0.0512881	0.2161955
South Africa						
ECT	-0.8628654	0.2432718	-3.55	0.000	-1.339669	-0.3860613
A	0.0149974	0.1249845	0.12	0.904	-0.2299678	0.2599625

Appendix 5 Short-term coefficients by country

Dependent variable: LS						
B	-0.0006294	0.0016234	-0.39	0.698	-0.0038112	0.0025523
Y	-0.0045724	0.0095426	-0.48	0.632	-0.0232754	0.0141307
C	0.4054783	0.1177535	3.44	0.001	0.1746857	0.6362708
Turkey						
ECT	-0.1477139	0.1053227	-1.40	0.161	-0.3541425	0.0587148
A	-0.2191391	0.1378022	-1.59	0.112	-0.4892265	0.0509483
B	0.0003578	0.0013464	0.27	0.790	-0.0022811	0.0029968
Y	0.0008721	0.0045074	0.19	0.847	-0.0079623	0.0097066
C	0.0870817	0.0567261	1.54	0.125	-0.0240995	0.1982628

Author contributions The paper was written collaboratively by the authors. The final manuscript was read and approved by both authors.

Funding Open access funding provided by the Scientific and Technological Research Council of Türkiye (TÜBİTAK).

Data availability On request, the authors will provide the data that supports the conclusions of this study.

Declarations

Ethical approval Not applicable.

Conflict of interest There are no competing interests declared by the author.

References

AA. (2023). Ünlü İngiliz ekonomist O'Neill: Türkiye, genişleyen BRICS'in parçası olacak bir ülke. https://www.aa.com.tr/tr/ekonomi/-unlu-ingiliz-ekonomist-o-neill-turkiye-genisleyen-brics-in-parcasi-olacak-bir-ulke/2894650. Accessed on 15 July 2024.

Al, İ. (2019). Sürdürülebilir Kalkınma Ve Yeşil Ekonomi: Türkiye İçin Bir Endeks Önerisi. *Hitit Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, *12*(1), 112–124. https://doi.org/10.17218/hititsosbil.473413

Andronova, I., & Sakharov, A. (2022). BRICS Sustainable Development Index: Methodological aspects. *International Organisations Research Journal*, *17*(3), 23–47. https://doi.org/10.17323/1996-7845-2022-03-02

Angell, L. C., & Klassen, R. D. (1999). Integrating environmental issues into the mainstream: An agenda for research in operations management. *Journal of Operations Management*, *17*(5), 575–598. https://doi.org/10.1016/S0272-6963(99)00006-6

Barrera-Roldán, A., & Saldıvar-Valdés, A. (2002). Proposal and application of a Sustainable Development Index. *Ecological Indicators*, *2*(3), 251–256. https://doi.org/10.1016/S1470-160X(02)00058-4

BBC (2023). BRICS: Grupta hangi ülkeler var, amaçları ne? https://www.bbc.com/turkce/articles/c0j3zwvjw3jo. Accessed on 01 December 2023.

Bhattacharya, S., & Dasgupta, S. (2019). Sustainable development in India: An analysis of economic, social, and environmental sustainability. *Journal of Environmental Management*, *234*, 25–34.

Bravo, G. (2014). The human sustainable Development Index: New calculations and a first critical analysis. *Ecological Indicators*, *37*, 145–150. https://doi.org/10.1016/j.ecolind.2013.10.020

Brundtland, G. H. (1987). *World Commission on Environment and Development. Our common future*. UN.

Dasgupta, P. (2007). The idea of sustainable development. *Sustainability Science*, *2*, 5–11. https://doi.org/10.1007/s11625-007-0024-y

Destek, G., Hossain, M. R., Aydın, S., & Destek, M. A. (2023). Can the resource curse be reversed through financialization, human capital, and institutional quality? Evidence from Sustainable Development Index. *Resources Policy*, *86*, 104245. https://doi.org/10.1016/j.resourpol.2023.104245

Frontiers in Sustainable Development. (2020). *Sustainable development efficiency and its influencing factors across BRICS and G7 countries: An empirical comparison*. Retrieved from Frontiers.

Garetti, M., & Taisch, M. (2012). Sustainable manufacturing: Trends and research challenges. *Production Planning & Control*, *23*(2–3), 83–104. https://doi.org/10.1080/09537287.2011.591619

Goodland, R. (1995). The concept of environmental sustainability. *Annual Review of Ecology and Systematics*, *26*(1), 1–24.

Hai, P. V., Thuy, N. T. D., Hang, P. T. T., Khoi, D. N. Assessment of Sustainable Development for Ly Son and Phu Quy Islands Using Sustainable Development Index. International Conference on Geo-Spatial Technologies and Earth, & Resources (2022). https://doi.org/10.1007/978-3-031-17808-5_21

Hass, J. L., Brunvoll, F., & Hoie, H. (2003). Overview of sustainable development indicators used by national and international agencies (OECD Statistics Working Papers 2002/2). Organisation for Economic Co-operation and Development. https://doi.org/10.1787/18152031

Hickel, J. (2020). The sustainable development index: Measuring the ecological efficiency of human development in the anthropocene. *Ecological Economics*, *167*, 1–10. https://doi.org/10.1016/j.ecolecon.2019.05.011

Jabareen, Y. (2008). A new conceptual framework for sustainable development. *Environment Development and Sustainability*, *10*, 179–192. https://doi.org/10.1007/s10668-006-9058-z

Jeronen, E. (2020). Sustainable development. *Encyclopedia of sustainable management* (pp. 1–7). Springer.

Jiang, Y., & Shi, C. (2023). Estimating sustainability and regional inequalities using an enhanced sustainable development index in China. *Sustainable Cities and Society*, *99*, 1–9. https://doi.org/10.1016/j.scs.2023.104555

Jin, H., Qian, X., Chin, T., & Zhang, H. (2020). A global assessment of sustainable development based on modification of the human development index via the entropy method. *Sustainability*, *12*(8), 3251. https://doi.org/10.3390/su12083251

Karadaş, H. A. (2020). Effect of labor force education level on growth: An analysis on fragile five countries. *Contemporary Approaches in the Field of Economy Finance and Management*, 43–58.

Karadaş, H. A. (2021). Yüksek Eğitim Seviyesine Sahip İşgücü Ekonomiye Katkı Yapar Mı? Gelişmiş Ülkeler Üzerine Bir Analiz. *Kesit Akademi Dergisi*, *7*(28), 433–450.

Khanova, O., Matyushenko, I., Kochańska, E., Tretyak, V., & Tofaniuk, O. (2021). *Calculation of sustainable development index in the Eu and Ukraine*. Acta Innovations.

Kothari, R. (1990). Environment, technology and ethics. *Technology and Values: Essential Readings*, 431–453.

Krajnc, D., & Glavič, P. (2005). A model for integrated assessment of sustainable development. *Resources Conservation and Recycling*, *43*(2), 189–208. https://doi.org/10.1016/j.resconrec.2004.06.002

Li, L., Wu, F., Cao, Y., Cheng, F., Wang, D., Li, H., Yu, Z., & You, J. (2022). Sustainable development index of shale gas exploitation in China, the UK, and the US. *Environmental Science and Ecotechnology*, *12*, 100202. https://doi.org/10.1016/j.ese.2022.100202

López, M. V., Garcia, A., & Rodriguez, L. (2007). Sustainable development and corporate performance: A study based on the Dow Jones sustainability index. *Journal of Business Ethics*, *75*, 285–300. https://doi.org/10.1007/s10551-006-9253-8

López-Penabad, M. C., Iglesias-Casal, A., & Rey-Ares, L. (2022). Proposal for a sustainable development index for rural municipalities. *Journal of Cleaner Production*, *357*, 1–17. https://doi.org/10.1016/j.jclepro.2022.131876

Luan, W., Lu, L., Li, X., & Ma, C. (2017). Weight determination of sustainable development indicators using a global sensitivity analysis method. *Sustainability*, *9*(2), 1–13. https://doi.org/10.3390/su9020303

Mehmood, B., Raza, S. H., & Mureed, S. (2014). Health expenditure, literacy and economic growth: PMG evidence from Asian countries. *Euro-Asian Journal of Economics and Finance*, *2*(4), 408–417.

Moffatt, I. (1996). *Sustainable development: Principles, analysis and policies*. The Parthenon Publishing Group Limited.

Mori, K., & Christodoulou, A. (2012). Review of sustainability indices and indicators: Towards a new City Sustainability Index (CSI). *Environmental Impact Assessment Review*, *32*(1), 94–106. https://doi.org/10.1016/j.eiar.2011.06.001

OECD (2024). Sustainable Development Goals (SDGs). https://www.oecd.org/en/topics/sustainable-development-goals-sdgs.html. Accessed on 15 July 2024.

Özbek, S. (2023). The determinants of Energy Intensity in Energy Importing developing countries. *Cumhuriyet Universitesi Journal of Economics & Administrative Sciences*, *24*(1), 114–126. https://doi.org/10.37880/cumuiibf.1181547

Parris, T. M., & Kates, R. W. (2003). Characterizing and measuring sustainable development. *Annual Review of Environment and Resources*, *28*(1), 559–586. https://doi.org/10.1146/annurev.energy.28.050302.105551

Peng, Y., & Zhang, H. (2022). Global sustainable development evaluation methods with Multiple-Dimensional: Sustainable Development Index. *Frontiers in Environmental Science*, *10*, 957095. https://doi.org/10.3389/fenvs.2022.957095

Pesaran, M. H., & Smith, R. (1995). Estimating long-run relationships from dynamic heterogeneous panels. *Journal of Econometrics*, *68*(1), 79–113. https://doi.org/10.1016/0304-4076(94)01644-F

Pesaran, M. H., Shin, Y., & Smith, R. P. (1999). Pooled mean group estimation of dynamic heterogeneous panels. *Journal of the American Statistical Association*, *94*(446), 621–634.

Sage, A. P. (1999). Sustainable development: Issues in information, knowledge, and systems management. *Information Knowledge Systems Management*, *1*(3–4), 185–223.

Şahin, U., & Kula, M. E. (2015). Assessing sustainable development in Turkey: An analysis of economic, social, and environmental sustainability. *Sustainability*, *7*(6), 8561–8577.

Sakalsız, S. A., & Kılıç, M. (2024). The relationship between Sustainable Development Index and Financial Development and Globalization in developed and developing countries. *Alanya Akademik Bakış*, *8*(1), 145–158. https://doi.org/10.29023/alanyaakademik.1287919

Salvati, L., & Carlucci, M. (2014). A composite index of sustainable development at the local scale: Italy as a case study. *Ecological Indicators*, *43*, 162–171. https://doi.org/10.1016/j.ecolind.2014.02.021

Singh, A. K., Jyoti, B., Kumar, S., & Lenka, S. K. (2021). Assessment of global sustainable development, environmental sustainability, economic development and social development index in selected economies. *International Journal of Sustainable Development and Planning*, *16*(1), 123–138. https://doi.org/10.18280/ijsdp.160113

Sun, J., Jin, H., Tsai, F. S., & Jakovljevic, M. (2022). A global assessment of sustainable development: Integrating socioeconomic, resource and environmental dimensions. *Frontiers in Energy Research*, *10*, 816714. https://doi.org/10.3389/fenrg.2022.816714

Sustainable Development Goal Interactions (2021). Retrieved from Springer.

Sustainable Development in BRICS Countries: From Concept to Practice (2018). Retrieved from Springer.

Thamrin N, Wulansari IY, Irawan PB (2023) Measuring the performance of Sdgs in provincial level using regional sustainable development index. *Journal of Environmental Science and Sustainable Development*, *6*(2), 294–314. https://doi.org/10.7454/jessd.v6i2.1176

Turturean, C. I., Asandului, L. A., Chirila, C., & Homocianu, D. (2019). Composite Index of Sustainable Development of EU Countries'economies (ISDE-EU). *Transformations in Business & Economics*, *18*(2A), 586–604.

United Nations Department of Economic and Social Affairs (UNDESA) (1992). Agenda 21: Earth Summit - The United Nations Programme of Action from Rio. United Nations.

Wang, C., Wang, L., Zhai, J., Feng, T., Lei, Y., Li, S., Liu, Y., Liu, Y., Hu, Z., & Zhu, K. (2024). Assessing progress toward China's subnational sustainable development by Region Sustainable Development Index. *Sustainable Horizons*, *11*, 100099. https://doi.org/10.1016/j.horiz.2024.100099

Wu, J., & Wu, T. (2012). Sustainability indicators and indices: an overview. Handbook of sustainability management, 65–86.