

## Research Article | Araştırma Makalesi

# The relationship between innovation and sustainable development: A comparative analysis

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## Abstract

Sustainability and innovation are critical concepts in today's global competition, and it is widely accepted that these two concepts support each other. "Sustainable Development Index" and "Global Innovation Index" are well-known indices for evaluating the sustainability and innovation status of countries in detail. Although much research has been conducted by considering these two concepts, none of the studies have the sub-breakdowns of the indices examined comparatively based on real-time data. In this study, research was planned on the Global Innovation Index (GII) and Sustainable Development Index (SDI) 2023 data to understand the relationship between innovation and sustainability by using both document and quantitative analysis. Document analysis is used to find out the crucial sustainability goals that need to be examined for innovative countries. The results show that although there is a strong relationship between innovation and sustainability, some sub-indices of sustainable development goals are neglected by innovative countries, and quality of education has a mediator role on economic growth and responsible production and consumer behaviors.

**Keywords:** Innovation, Corporate Governance, Sustainability, Strategic Management

**JEL Codes:** L1, L2, C13, M1

## İnovasyon ve sürdürülebilir kalkınma arasındaki ilişki: Karşılaştırmalı bir analiz

### Öz

Sürdürülebilirlik ve inovasyon (yenilik) günümüz küresel rekabetinde kritik kavramlardır ve bu iki kavramın birbirini desteklediği genel olarak kabul edilmektedir. "Sürdürülebilir Kalkınma Endeksi" ve "Küresel İnovasyon Endeksi" ülkelerin inovasyon ve sürdürülebilirlik konumlarını detaylı bir şekilde raporlayan endekslerin başında gelmektedir. Bu iki kavramı dikkate alan birçok araştırma yapılmış olmasına rağmen, incelenen endekslerin alt kırılımlarını gerçek zamanlı verilere dayanarak kıyaslamalı olarak açıklayan bir çalışma yapılmamıştır. Bu çalışmada, inovasyon ve sürdürülebilirlik arasındaki ilişkiyi ortaya çıkarmak için 2023 Küresel İnovasyon Endeksi (GII) ve Sürdürülebilir Kalkınma Endeksi (SDI) verileri kullanılarak döküman analizi ve nicel analiz yöntemlerinin her ikisi de uygulanmıştır. Döküman analizi yenilikçi ülkeler için kritik öneme sahip olan sürdürülebilirlik hedeflerinin tespiti için kullanılmıştır. Sonuçlar, inovasyon ve sürdürülebilirlik arasında güçlü bir ilişki olmasına rağmen, yenilikçi ülkeler tarafından bazı sürdürülebilir kalkınma hedeflerinin alt endekslerinin göz ardı edildiğini göstermektedir. Ayrıca, eğitim kalitesinin ekonomik gelişim sürdürülebilirliği ile sorumlu üretim ve tüketim davranışları üzerinde aracılık rolü oynadığı sonucuna varılmıştır.

**Anahtar Kelimeler:** İnovasyon, Kurumsal Yönetim, Sürdürülebilirlik, Stratejik Yönetim

**JEL Kodları:** L1, L2, C13, M1

## Introduction

Today, the concepts of sustainability and innovation have a central role in the transformation of the global economy. Sustainability was defined in the 1987 Brundtland Report as "meeting the needs of present generations without compromising the ability of future generations to meet their own needs." This definition emphasizes that economic development should be considered in balance with environmental and social dimensions. Innovation, on the other hand, refers to the development and dissemination of new products, processes, business models and services. In conditions of global competition, the role of innovation in supporting sustainable development is increasingly accepted.

There are various indexes that address innovation and sustainable development and evaluate countries in these contexts with various dimensions and criteria. Among these indexes, the internationally accepted and the most common ones are discussed.

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The Sustainable Development Index (SDI) was developed to measure countries' performance in achieving the 17 Sustainable Development Goals (SDGs) set by the United Nations. The index uses social, economic and environmental indicators to assess countries' progress towards sustainable development. These indicators include issues such as reducing poverty, access to clean energy, eliminating inequalities, innovation infrastructure and combating climate change.

The changes in technology are rapidly spreading, affecting every sector worldwide in terms of management, production, trade, and financial systems. This shift has transformed the relationship with paper and pen into a profession that encompasses computers, applications, and software. With the influence of artificial intelligence in every field, people prefer to rely on accurate data and information to survive, ensure sustainability, and achieve set goals (Yaylalı, 2024). In a digitalized world, industries and firms increasingly compete and organize themselves around innovation by leveraging advanced technologies. The processes for developing new products and services have evolved significantly, driven by digital tools that enhance collaboration, streamline workflows, and foster creativity on new product development and positioning companies to thrive in a rapidly changing Marketplace (Appio et.al., 2021). The emergence of easily accessible market structures due to technological and industrial developments has increased competition while decreasing natural resources and environmental values. Globalization increases widespread industrial production, the emergence of new pollutants due to Technologies and the development of transportation facilities. Increased urbanization, accelerated resource use, population growth, poverty, and similar developments that cause environmental problems are transferring localized environmental degradation to a global scale. The emergence and magnitude of environmental issues can increase depending on the size and continuity of pollutants, the capacity of nature to absorb these pollutants, and the awareness shown towards them (Yücel and Terzioğlu, 2023).

It is often emphasized that the concepts of sustainability and innovation are related to each other. Porter and van der Linde (1995) stated that innovation can increase environmental and economic sustainability by providing competitive advantage. At the same time, Hart and Milstein (2003) also emphasized that sustainability-oriented innovation strategies can provide long-term competitive advantage. In this context, it is accepted that innovation is a tool to achieve sustainability goals and that sustainable development goals encourage the continuity of innovation. However, due to issues such as capital shortages, lack of institutional infrastructure and policy alignment regarding environmental problems, difficulties in developing clear policy measures, limited public participation, and human infrastructure in underdeveloped and developing economies, hinder the sustainable development applications. To manage the environment and environmental innovation sustainably, there is a need for legal and administrative regulations as well as institutions and systems to implement them (Özen ve Terzioğlu, 2023).

The Global Innovation Index (GII) provides a comprehensive framework to evaluate the innovation capacity and performance of countries. Prepared by the World Intellectual Property Organization (WIPO), Cornell University and INSEAD, the index includes more than 80 indicators such as innovation infrastructure, human capital, knowledge production and technology outputs. GII is considered an important tool in shaping countries' innovation policies.

Sustainability is not just a concept focused on the overconsumption of resources and their continuity; it is also a transformative process that requires economic, social, and environmental integrity. Every step taken toward environmentalism, whether at the public or private sector level, is important and necessary. In this context, organizations are entities that can contribute to the creation of a sustainable culture, and this can be reinforced through various environmental values—such as eco-friendly identity and behavior, ecological markets, and consumer awareness. Corporate governance particularly those related to the environmental component of sustainability, play a significant role in helping organizations achieve their global sustainability goals and objectives (Köşker and Güner, 2020). Sustainability and corporate governance are frequently seen as distinct concepts, with less emphasis on their overlapping areas. Social sustainability plays a crucial role in improving the performance aspects that companies should prioritize. It also supports the vision and societal objectives that corporations should target, including environmental protection, social justice, equity, and economic growth. This involves outlining the governance framework that dictates how the company operates, including its business model, strategic initiatives, objectives, as well as the management of risks, performance assessments, and reward systems. It focuses on how these elements are directed and controlled to ensure the organization functions effectively and achieves its goals. (Chandrakant and Rajesh, 2022). The worldwide challenge of sustainable development involves the intricate connections between environmental change, socio-economic growth, and harmonious coexistence with the significant support of the firms (Virji et.al., 2019).

The aim of this study is to evaluate the relationship between innovation and sustainability on a global scale. The top 10 countries in the Global Innovation Index and Sustainable Development Index in 2023 were compared and the relationship between them was analysed. Our research's question is "Are countries that are successful in innovation also successful in their sustainability goals?" The reverse of this problem has also been examined, with the assumption that both concepts should support each other.

The contribution of this study is to comparatively examine and evaluate the relationship between innovation and sustainability based on real data and to offer suggestions for the development of areas open to improvement. In the literature, the strong

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relationship between innovation and sustainability has been revealed in many studies. However, it is important to understand how the two concepts are related to each other through real index data. In this context, the study addresses the following questions:

1. Are the countries that rank high in the Innovation Index also successful in the Sustainable Development Index?
2. Can the countries in the top 10 in the Sustainable Development Index show the same success in innovation performance?
3. Which sustainability development goals have significant effect on innovation index ranking. Thus which sustainability development goals have not priority for innovative countries.

The findings obtained in the study point out the importance of considering innovation and sustainability policies together.

## 1. Literature Review

The relationship between sustainability and innovation has been a long-discussed issue in the literature. Porter and van der Linde (1995) stated that innovation can increase environmental and economic sustainability by providing competitive advantage. At the same time, Hart and Milstein (2003) also emphasized that sustainability-oriented innovation strategies can provide long-term competitive advantage. International indexes such as the Global Innovation Index (GII) and Sustainable Development Index (SDI) are important tools for measuring and comparing the innovation and sustainability performances of countries. For example, Dutta and Lanvin (2013) stated that the Global Innovation Index plays a critical role in shaping countries' innovation policies. Likewise, the Sustainable Development Index developed by Sachs et al (2018) measures countries' progress in achieving the United Nations Sustainable Development Goals. Kwatra et al. (2020) defined the basic components of sustainable development and analysed how different indexes evaluate these components. In their studies, they emphasized that sustainable development and innovation are concepts that support each other, but the methods of different indexes to evaluate these concepts vary. Ness et al. (2007) pointed out the difficulties of measuring sustainable development and stated that valuation methods that integrate ecological, social and economic indicators should be developed. Terzioğlu et.al. (2020), has a Research for the year 2018, based on the urban innovation indicators obtained, it has been determined that research and development activity indicators and environmental activity indicators negatively affect urbanization. In contrast, activities showing investments in health, infrastructure activity indicators, and individual investment-savings indicators have a positive impact on urbanization. Kennedy et.al., (2017) argue that adopting sustainability as a key strategic driver for new business initiatives promotes the creation of innovative bio-based products, which facilitates a transition in the value chain away from petrochemical reliance. This shift not only supports environmental goals but also opens up new market opportunities and enhances overall business resilience. To understand the relationship between sustainability and innovation at the policy level, Perrini et al. (2011) stated that innovation is an important tool in increasing sustainability performance. Additionally, Schaltegger and Wagner (2011) demonstrated the potential of sustainability-focused innovation strategies to provide competitive advantage. Albert (2019), finds a strong positive correlation between frugal innovation and ecological sustainability. Frugal innovation is fundamentally designed to be socially and economically sustainable, as it focuses on creating affordable solutions that meet the needs of underserved populations. Moreover, this approach holds significant promise for advancing ecological sustainability by promoting resource efficiency and reducing waste. By leveraging limited resources creatively, frugal innovation can lead to environmentally friendly products and processes that contribute to a more sustainable future. Terzioğlu et al., (2021), investigate the effects of the number of individuals receiving social services in cities, considered as a social innovation indicator, as well as the export, entrepreneurship, and average daily income levels of cities, viewed as incremental innovation indicators, on the migration rates of those cities for the years 2011-2018. It is concluded that, countries can achieve high-quality labor, efficient and regular migration mobility, which can expand national research and development systems, integrate their markets with the international market, elevate the level of entrepreneurship, improve the national division of labor through interactions between regions that receive and give migration, and overcome regional labor supply shortages. Inigo et.al., (2020), companies focusing on Sustainability Oriented Innovation can achieve greater advantages from open innovation by collaborating within their current portfolio, which is also advantageous for identifying disruptive partners. Nevertheless, none of the studies conducted have compared the detailed breakdowns of these indexes, nor have they evaluated them using real-time data. This gap highlights the need for a more comprehensive analysis to understand the full impact of these collaborations. In this study, research was planned on Global Innovation Index (GII) and Sustainable Development Index (SDI) 2023 data to understand the relationship between innovation and sustainability.

## 2. The Concept of Sustainability and Innovation

### 2.1. Sustainability Development Index (SDI)

Sustainability is defined as the ability of a society, ecosystem or any continuous system to continue its work without interruption, without deterioration, without depleting with excessive use or without overloading the main resources, which are the vital link of the system. The basis of sustainable development is the protection and development of resources. Due to the negative impact of human-industrial activities on the environment causing concerns for the future, the concept of sustainable development has emerged. This concept considers environmental issues, sees ecological balance and economic growth as a whole, ensures the effective use of scarce resources, and expresses the ability to meet future needs while addressing current needs. In the concept of sustainable development, the phenomena of environment and growth are addressed together instead of growth being prioritized over the environment, thus encompassing both development and social components (Özen ve Terzioğlu, 2023). Continuously protecting and utilizing resources, especially supporting the development of renewable resources without exceeding their renewal limits, forms the basis of the development philosophy that protects the environment (Çemrek and Bayraç, 2013). In the context of sustainable development indicators, the sustainable development indicator set prepared by the European Union (EU) is taken as basis (Kwatra et al., 2020). Sustainability is generally discussed under three headings: economic dimension, social dimension and environmental dimension.

**Economic dimension;** It expresses that every resource on earth is limited and how these resources can be distributed most equitably in a way that will increase people's quality of life. An economically sustainable system is one that can produce goods and services according to continuity principles, takes sectoral balances into account and ensures manageability of debts.

**Social dimension;** It aims at adequate and equal distribution of social services such as education and health, gender equality, political responsibility and participation. Social dimension fosters the well-being of societies and global peace for sustainability of corporations and restfulness of countries. This dimension also helps countries to go through common targets for the sake of the world's well-being.

**Environmental dimension;** It aims to use every natural resource, whether recyclable or not, in a way that can ensure its continuity. The aim here is to ensure that ecosystems adapt to changing conditions (Tıraş, 2012). One of the most important actors at the intersection of these elements is innovation. Innovation changes and transforms society, economy and environment with its positive or negative effects. Today, R&D is mentioned together with innovation and is included in the literature as Research & Development & Innovation. The biggest challenge in indices measuring sustainable development is to find a conciling valuation method in terms of science, applied policies and ecosystem protection. Such an evaluation necessitates the integration of environmental and social factors with scientific development. Sustainability indexes provide guidance on three issues. It integrates ecological and social systems, allows us to see the sustainability trend on a global level, guides politicians in their future plans by making short-term evaluations (Nesset et al., 2007).

The Sustainable Development Index is one of the indexes that makes the most detailed evaluation based on the sustainable development goals determined by EU. The main headings and subheadings of this index are given in Table 1.

**Table 1.** Sustainable Development Index

Main Headings	Goals	Summarized subheadings
No Poverty	SDG1	Poverty rates after taxes, Poverty headcount ratio
Zero Hunger	SDG2	Prevalence of undernourishment, obesity, exports of hazardous pesticides
Good Health & Well-Being	SDG3	Maternal mortality rate, Incidence of tuberculosis, New HIV infection, Death rate due to cardiovascular diseases, cancer aged 30-70.
Quality Education	SDG4	Participation in pre-primary organized learning, PISA score.
Gender Inequality	SDG5	Ratio of female to male mean years of education, seats held by women in parliament, Gender wage gap
Clean Water & Sanitation	SDG6	Population using basic drinking water services, Population using safely managed sanitation services
Affordable and Clean Energy	SDG7	Population with access to electricity, fuel and technology. Renewable energy share/total energy consumption
Decent Work and Economic Growth	SDG8	Adjusted GDP growth, fundamental labour rights are effectively guaranteed

Table 1. Continue.

Reduced Inequalities	SDG10	Reduce inequalities within and among countries
Sustainable Cities and Communities	SDG11	Make cities inclusive, safe and sustainable
Responsible Consumption and Production	SDG12	Electronic waste, Production-based SO2 emissions, Production-based nitrogen emissions, Export of plastic waste, non-recycled municipal solid waste
Climate Action	SDG13	CO2 emission from fossil fuel combustion, CO2 emission embodied in imports, Carbon pricing score
Life Below Water	SDG14	Mean area that is protected in marine sites and biodiversity.
Life on Land	SDG15	Mean area that is protected in terrestrial sites for species survival.
Peace, Justice, Institutions	SDG16	Homicides, population who feel safe walking alone at night, people in prison
Partnerships for the Goals	SDG17	Government spending on health and education.

Source: Kwatra et.al., 2020

## 2.2. Innovation Concept and Global Innovation Index

Innovation is recognized for generating economic and social value by creating high-value outputs while utilizing the same resources (Ayçin & Çakın, 2019; Baş, 2013; Elmacı & Yalçın, 2013). For this reason, businesses focus on innovation to increase productivity and provide sustainable competitive advantage (Göker, 2001; Hancıoğlu & Yeşilaydın, 2016). Innovation is viewed as a crucial factor that enhances not only business performance but also the productivity, well-being, and competitiveness of nations (Karaata, 2012). The significance and recognition of innovation are growing steadily among both institutions and national economies. However, the notion that innovation is a readily available tool or a one-time solution is a misconception. Sustainable conditions are essential for fostering innovation, as efforts that lack sustainability will not yield lasting benefits. The success of innovation applications often depends on verifiable mechanisms and observable processes. However, at the national and local levels, innovative activities frequently face challenges such as the lack of qualified personnel, high costs, insufficient investment, technological inadequacies, uncertainty in demand for innovative applications, and deficiencies in infrastructure (Yücel and Terzioğlu, 2023). Each innovation risks losing its competitive edge due to factors such as the introduction of similar products or changes in consumer needs. To maintain the advantages offered by innovative products and services, it is crucial to embed innovation as a sustainable business function and integrate it into the corporate culture. Achieving this requires the establishment of a robust innovation management system, which should include a methodology for effectively managing the processes of measurement, incentives, strategy, and action (Elmacı & Yalçın, 2013; Karaata, 2012; Taşgit & Torun, 2016). The most critical step among these processes is to measure the innovation performance of the business (Elverdi & Atik, 2020; İnel & Türker, 2016; Karaata, 2012; Süt & Çetin, 2018).

This metric not only assesses the shift in innovation performance but also evaluates the efficiency of the resources dedicated to innovation. (Ayçin & Çakın, 2019; Kalender et al., 2014). Drawing from Drucker's principle that "you can't control what you can't measure, and you can't manage what you can't control," it emphasizes that planning informed by data derived from measurements is crucial for creating a successful innovation system and ensuring its sustainability (Drucker, 2014). The Global Innovation Index (GII) Project studies were first initiated in France in 2007 by the European Institute of Business Administration INSEAD under the leadership of Prof. Dr. Soumitra Dutta, and then continued to develop with the support of Cornell University and the World Intellectual Property Organization WIPO. In this context, the index aims to determine the relative innovation capacities of countries and to reveal the strengths and weaknesses of countries in terms of innovation policies and practices (Dutta et al., 2021; INSEAD, 2020). In addition, it focuses on developing ways to measure innovation and understanding innovation and focuses on defining good practices and targeted policies (INSEAD, 2020). This project, which offers a very holistic and comprehensive assessment opportunity on innovation, focuses on innovation inputs and outputs by dividing it into 7 dimensions and approximately 80 indicators to examine the multidimensional aspects of innovation. The index is prepared regularly every year in cooperation with WIPO, INSEAD and Cornell University. This index, which provides a detailed metric tool covering 141 countries, represents 95.1% of the world's population and 98.6% of the world's GDP (Hancıoğlu, 2016; INSEAD, 2020).

In Table 2, it is seen that the innovation input sub-index of the Global Innovation Index covers the dimensions of institutions, human capital and research, infrastructure, market development and commercial development; and the innovation output sub-index covers the dimensions of knowledge and technology together with creative outputs.



**Table 2.** Global Innovation Index Indicators

Dimensions	Criteria
Innovation Input Sub-Index	
Institutions	Political environment, Regulatory environment, Business environment
Human Capital and Research	Education, Higher Education, Research and development
Infrastructure	Information and communication technologies, General infrastructure, Ecological sustainability
Development of Markets	Credit, Investment, Trade and Competition
Commercial Development	Knowledge workers, Innovation connections, Knowledge internalization
Information and Technology Outputs	Knowledge production, Knowledge impact, Knowledge dissemination
Creative Outputs Creative intangibles, Creative products and services,	Creative Outputs Creative intangibles, Creative products and services,

Source: Dutta et al., 2021

### 3. Methodology

Two different methodologies which are document analysis and quantitative analysis are used in this research. In document analysis the issues which should be focused are determined by evaluating country reports of top ten ranking countries in both indexes. Regression and correlation analysis are executed between "Global Innovation Index" 2023 scores and the sub-indices scores of "Sustainable Development Index" 2023 which are determined by document analysis.

#### 3.1. Document Analysis

In this study, the relationship between innovation and sustainability is analysed in two different parts. In the first part 2023 data from the Global Innovation Index (GII) and the Sustainable Development Index (SDI) are collected and below mentioned stages are followed:

Data Collection;

GII Data: It is taken from the 2023 Global Innovation Index report published by the World Intellectual Property Organization (WIPO). SDI Data: It is taken from the 2023 Sustainable Development Index report published by the Sustainable Development Solutions Network (SDSN). The countries ranked in the top 10 of the GII and SDI indexes have been examined comparatively.

Data Analysis;

The rankings of the countries in both indexes have been examined comparatively, and the relationship between innovation and sustainability performance has been analysed by examining the country reports in detail and evaluating the scopes of the sub-components using document analysis.

Additionally, the performance of countries that excel in both indexes has been evaluated by identifying the points of convergence and divergence in their subindex performances. Both indexes' country reports for 2023 have been examined through detailed document review. In these reports, the dimensions and criteria of the indexes have also been investigated in detail and tables are prepared that summarize the intersection points of the countries that are placed in the top of both index rankings.

The table 3 below shows the rankings of the countries in the top 10 of the 'Sustainable Development Index' (SDI) with their scores in the 'Global Innovation Index.' (GII) Finland, Sweden, Denmark, and Germany are among the top ten in both indexes.

**Table 3.** The Top Ten Scored Countries In The SDI With Their GII Scores

Country	Sustainable Development Index Ranking	Global Innovation Index Ranking
Finland	1	6
Sweden	2	2
Denmark	3	9
Germany	4	8
Austria	5	18
France	6	11
Norway	7	19
Czechia	8	31
Poland	9	41
Estonia	10	16

In Table 3, it can be observed that six of the countries ranked in the top 10 of the 'Sustainable Development Index', except for four, are ranked 11th, 16th, 18th, 19th, 31st, and 41st in the 'Global Innovation Index. In Table 4, the rankings of the countries in the top 10 of the 'Global Innovation Index 2023' are shown comparatively to their rankings in the 'Sustainable Development Index 2023.' Only four of the countries in the top 10 of the 'Global Innovation Index' are also in the top 10 of the 'Sustainable Development Index 2023.' These countries are Sweden, Finland, Germany, and Denmark.

**Table 4.** The Top Ten Countries Ranked In GII with their SDI Scores

Country	Global Innovation Index	SDI
Switzerland	1	15
Sweden	2	2
U.S.A.	3	39
U.K.	4	11
Singapore	5	64
Finland	6	1
Netherlands	7	20
Germany	8	4
Denmark	9	3
South Korea	10	31

To provide detailed comments, the dimensions and criteria of the indexes have been examined. The rankings and scores of the countries that are common in the top 10 of both indexes have also been included in the analysis and evaluated comparatively. To interpret the similarities and differences among the countries, the dimensions in which each country received high and low scores have been identified through this comparison. It is observed that the top ranking countries in innovation index are the ones that developed economically and socially.

Document Review implications are;

- In the Sustainable Development Index, technological and scientific development is considered. Ecological sustainability and general infrastructure are considered in the Global Innovation Index alike. These two indexes have some common sub-dimensions with each other. Among the countries in the top 10 of the Sustainable Development Index, only four are also in the top 10 of the Global Innovation Index. These countries are; Finland (SDI: 1, GII: 6), Sweden (SDI: 2, GII: 2), Denmark (SDI: 3, GII: 9), Germany (SDI: 4, GII: 8).

- Some countries that rank high in the Global Innovation Index are positioned much lower in the Sustainable Development Index. For example, the United States, which ranks 3rd in the Global Innovation Index, is 39th in the Sustainable Development Index. Singapore, ranked 5th in the Global Innovation Index, is 64th in the Sustainable Development Index. Similarly, South Korea, which is 10th in the Global Innovation Index, ranks 31st in the Sustainable Development Index. Switzerland, ranked 1st in the GII, is 15th in the SDI. According to the index data, the main issues faced by countries are:

- Countries that rank high in the **Global Innovation Index** face challenges in converting the patents they obtain into products. There is also a decline in the number of students studying engineering in these countries. Some innovative and economically developed countries are exporting weapons and creates threat for global social peace.

- Countries in the top 10 of the **Sustainable Development Index** have not been able to achieve the set targets for air quality and responsible production & consumption targets. Decreasing inequalities is also neglected by the prominent countries of both indexes.

- Sweden has high scores in both indexes, achieving success in gender equality, access to energy, and poverty alleviation. Main sustainability topics that challenge innovative countries are listed in Table 7.

**Table 7.** Sustainability Goals Needed More Intention

Sustainable Development Goals (SDG)	SDG's Name
SDG 4	Quality Education
SDG 8	Decent Work and Economic Growth
SDG 10	Reduced Inequalities
SDG 12	Responsible Consumption and Production
SDG 13	Climate Action
SDG 16	Peace, Justice and Strong Institutions

Based on the topics derived from the document analysis are tested by quantitative Research for obtain more accurate results.

#### 4.2. Quantitative Analysis Based on the Document Analysis

In the first step of the quantitative analysis linear regression is executed in order to find out the cause effect relation between the variables. Top 50 ranking countries of 2023 innovation index are selected. The dependent variable is 2023 "Global Innovation Index" scores of top 50 ranked countries. The independent variables are "Sustainable Development Index" scores of Sustainable Development Goals 4-8-10-12-13 and 16. The interface "Jamovi" is used for the analysis which is an open-source statistical software. The descriptive statistics of the independent variables for top ranking 50 countries are given below in Table 8.

**Table 8.** Descriptive Statistics

	SDG16	SDG13	SDG12	SDG10	SDG8	SDG4
N	49	48	49	46	49	49
Missing	0	1	0	3	0	0
Mean	77	70.5	57.1	80.5	77.7	94.4
Median	79	75.5	56	83.5	79	96
Standard Deviation	11.3	16	13.4	19.2	6.07	5.56
Minimum	51	28	28	14	57	78
Maximum	93	94	83	100	86	100
Shapiro-Wilk W	0.951	0.896	0.986	0.851	0.859	0.827
Shapiro-Wilk P	0.042	< .001	0.826	< .001	< .001	< .001

The table presents statistical data for six Sustainable Development Goals (SDGs): **SDG16, SDG13, SDG12, SDG10, SDG8, and SDG4.**

**N (Sample Size):** All SDGs have a sample size of 46 to 49, indicating a relatively consistent number of observations. SDG10 has 3, SDG13 has 1 missing value. **Median** value is found by ordering all data points and picking out the one in the middle. Similar trends are observed in the median values, with SDG4 is the highest (96), SDG12 the lowest (56). The mean value provides a central measure of the data for each Sustainable Development Goal (SDG). While SDG4 demonstrates exceptional achievement, SDG12 stands out as an area in need of improvement. SDG10 has the highest standard deviation (19.2), indicating greater variability in scores. SDG4 has the lowest standard deviation (5.56), suggesting that scores are closely clustered around the mean. The Shapiro-Wilk test is a statistical test used to assess the normality of a dataset. A W value close to 1 indicates that the data is normally distributed normality. A p-value less than 0.05 typically indicates that the null hypothesis (that the data is normally distributed) can be rejected. Regression analysis is executed for finding cause effect relation between two variables which are the scores of first 50 countries in “Global Innovation Index 2023” and “Sustainable Development Index 2023”.

**Table 9.** Model Coefficients- GII 2023-SDI 2023

Predictor	Estimate	SE	t	P	Model	R	R <sup>2</sup>	F	P
Intercept	-12.592	18.562	-0.678	0.501	1	0.430	0.185		
SDG index	0.780	0.239	3.265	0.002					
ANOVA test								10.7	0.002

The **R** value represents the correlation coefficient, which indicates the strength of the relationship between the independent and dependent variables in the model.

In this case, the R value of 0.430 suggests a moderate positive correlation. Innovation has a positive significant effect on sustainability ( $\beta=0.430, p=.002$ ). The overall significance of the model can be seen from the ANOVA table and supported with the values  $F(1,47) = 10.7, p=.002$

The **R<sup>2</sup>** value, also known as the coefficient of determination, represents the proportion of the variance in the dependent variable that is explained by the independent variables in the model. Here, the R<sup>2</sup> value is 0.185, meaning the model explains 18.5% of the variance in the dependent variable. This analysis indicates that the model is significant, but the explained variance is limited. To test the robustness of the results, the same model was re-analyzed by using the bootstrap method in SPSS software (R=1000 sampling). In the bootstrap analysis, the estimated coefficient value for the innovation variable was obtained as 0.2369, with a standard error of 0.0835 and a bias value of -0.0035. The 95% BCa confidence interval is (0.0676, 0.3907) and does not include zero. This result indicates that the effect of the variable is statistically significant by using the bootstrap approach. The low bias value and narrow confidence interval support that the model is reliable, and the predictions are stable. Thus, both analysis which are executed by classical approach and bootstrap approach are in line with the significant effect of the variable innovation on the variable sustainability.

Correlation analysis is a statistical method used to evaluate the strength and direction of the linear relationship between two quantitative variables. It helps to understand how changes in one variable are associated with changes in other variables. Table 10 shows the correlations among independent variables and the dependent variable Global Innovation Index (GII).



**Table 10.** Correlation of Variables

	SDG16	SDG13	SDG12	SDG10	SDG8	SDG4
SDG16	1					
P value		-	-	-	-	-
SDG13		1				
P value	0.183	-	-	-	-	-
SDG12			1			
P value	0.037	<0.001				
SDG10				1		
P value	0.002	0.006	<0.001			
SDG8					1	
P value	0.132	0.163	0.959	0.240		
SDG4						1
P value	0.208	0.590	0.015	0.006	0.139	
Innovation Index						
P value	0.727	0.037	<0.001	0.099	0.048	0.001

Innovation Index Correlations;

SDG12 ( $p < 0.001$ ) means strong correlations, SDG10 ( $p=0.099$ ) marginally significant, SDG4 ( $p=0.001$ ) strong correlations. SDG10, SDG13 and SDG16 are not statistically significant at the 0.05 level.

Linear Regression Model is executed between dependent variable (Global Innovation Index 2023) and independent variables (SDG16, SDG13, SDG12, SDG10, SDG8, SDG4) to see the cause result effect.

**Table 11.** Linear Regression of Independent Variables with Dependent Variable

	Estimate	T	P	R	R <sup>2</sup>	Anova F	Anova P
Intercept	8.9820	0.309	0.759	0.653	0.426		
SDG16	-0.1099	-1.390	0.173			1.931	0.173
SDG13	-0.0960	-1.035	0.307			1.072	0.307
SDG12	-0.3041	-2.569	0.014			6.600	0.014
SDG10	-0.0679	-0.862	0.394			0.743	0.394
SDG8	0.4855	2.203	0.034			4.855	0.034
SDG4	0.4141	1.714	0.094			2.939	0.094

The model demonstrates moderate explanatory power. SDG12 is statistically significant ( $p < 0.05$ ), indicating a negative relationship with the dependent variable. For each unit increase in SDG12, the dependent variable decreases by approximately 0.3041 units. The regression analysis indicates two prominent variables that SDG12 negatively impacts the outcome, while SDG8 has a positive effect. SDG4 has p-value 0.094 which is marginally significant ( $p < 0.10$ ) suggesting a positive relationship with the dependent variable, but it does not meet the conventional threshold for significance. SDG16, SDG13, SDG 10 have no significant effect on the dependent variable. These variables are taken out the model. ANOVA test shows that while some individual predictors (like SDG12 and SDG8) show significant p-values (0.014 and 0.034, respectively), the overall model does not demonstrate a statistically significant effect.

**Table 12.1.** Linear Regression Analysis, Dependent Variable is "GII 2023"

	Estimate	T	P	Model	R	R <sup>2</sup>
Intercept	-7.479	-0.303	0.763	3	0.604	0.365
SDG12	- 0.271	- 3.008	0.004			
SDG8	0.359	1.877	0.067			
SDG4	0.455	2.040	0.047			

**Table 12.2** Anova test results of Model 3

	SDG4	SDG8	SDG12
ANOVA T	4.16	3.52	9.05
ANOVA P	0.047	0.067	0.004

R: 0.604 indicates a moderate correlation between the predictors and the dependent variable. R: 0.365 suggests that approximately 36.5% of the variance in the dependent variable is explained by the model. SDG12 has significant negative effect and SDG4 has significant positive effect on the dependent variable. When SDG16, SDG13, SDG10 are taken out of the model SDG4 becomes significantly effective while it was marginally effective in the previous analysis. SDG8 which has significant positive effect on dependent variable becomes less significant with p value 0.067 Therefore mediator effect of SDG4 is questioned and mediation effect analysis is executed.

**Table 13.1.** Mediation effect of SDG4 with %95 confidence interval

SDG4	Indirect effect Estimate	Direct effect Estimate	Total effect Estimate
SDG8	0.136	0.308	0.444
SDG10	0.0677	0.0500	0.1177
SDG12	-0.0792	-0.2556	-0.3348
SDG13	-0.0199	-0.1580	-0.1779
SDG16	0.0505	-0.0195	0.0310

**Table 13.2.** Mediation effect of SDG4 with %95 confidence interval

SDG4 Mediator	Z direct	Z indirect	P direct	P indirect	Total Z	Total P
SDG8	1.54	1.38	0.124	0.166	2.07	0.039
SDG10	0.714	1.871	0.475	0.061	1.725	0.085
SDG12	-2,86	-1,82	0.004	0.069	-3.76	<0.01
SDG13	-1.783	-0.428	0.075	0.669	-1.716	0.086
SDG16	-0.123	1.248	0.902	0.212	0.168	0.866

SDG4 has the indirect effect on SDG 8 that is estimated as 0.136. This means that there is an indirect or mediation effect of 0.136 on the total effect of 0.444 for SDG8. SDG4 has the total negative effect on SDG12 as 0.3348. SDG4 has no significant direct or indirect effect for other SDGs.

#### 4.3. Findings of the Analysis

Sustainability and innovation have a strong linear positive relation with each other.

Top ten innovative countries are examined by document analysis and found that although they have good scores in “Global Innovation Index” 2023, social sustainability items like peace, social inequalities, responsible consumption have rooms to achieve.

Innovation index scores are negatively correlated with responsible consumption and production and climate action. Peace, justice and strong institutions is the sustainability development goal which mostly need to be achieved.

Quantitative analysis executed on the scores of top 50 countries in “Global Innovation Index” 2023 supports the results of the document analysis. Quality of education has a mediator effect on responsible consumption and production and sustainable Economic growth.

#### Conclusion

This study analyses the relationship between innovation and sustainability using the 2023 data from the Global Innovation Index (GII) and the Sustainable Development Index (SDI). The findings indicate a strong relationship between innovation and sustainability, while also revealing inconsistencies between the sustainability performance and innovation rankings of certain countries.

Some countries that are ranked in the top 10 of the Sustainable Development Index are also ranked in top ten of the Global Innovation Index. For example, Finland (SDI:1, GII: 6), Sweden (SDI: 2, GII: 2), Denmark (SDI: 3, GII: 9), and Germany (SDI: 4, GII: 8) are all positioned near the top in both indexes. A clear alignment has been observed between the sustainability and innovation performances of these countries. Sweden, by ranking highly in both indexes, has achieved success in goals such as gender equality, access to energy, and poverty alleviation. However, some countries that rank in the top 10 of the Global Innovation Index are positioned lower in the Sustainable Development Index. For example, the United States (GII: 3, SDI: 39) and Singapore (GII: 5, SDI: 64), which are high-ranking in innovation, have lower rankings in sustainability performance. Countries like South Korea (GII: 10, SDI: 31) also exhibit similar discrepancies. These inconsistencies indicate that innovation policies are not fully integrated with sustainable development goals.

It is observed that some countries that are placed in the top 10 of the Sustainable Development Index sell weapons to other countries and have not been able to provide the targeted contributions to global peace. For example, countries like Switzerland, Sweden, and Germany face challenges in achieving sustainable development goals related to peace and justice. This situation highlights the importance of comprehensively addressing sustainable development goals.

Sweden, ranked 2nd in both the Sustainable Development Index and the Global Innovation Index, has been observed to achieve its goals in gender equality, access to energy resources, and poverty alleviation. However, it has been noted that countries in the top 10 of the Sustainable Development Index have not met the set targets for air quality and responsible production & consumption (Table 6). These countries have areas for improvement in increasing the share of renewable energy in total energy consumption. Additionally, with the rise in the number of young people who are neither in education nor in the workforce, there is a decline in labour productivity.

It has been observed that countries ranked highly in the Global Innovation Index face challenges in converting the patents they obtain into products. Additionally, there is a decline in the number of students studying engineering in these countries. Countries with strong performance in innovation have challenges to achieve goals in the “Sustainable Development Index” because of the following reasons:

### 1. Economic Priorities

Most countries that lead in innovation do not align their economic growth policies with the Sustainable Development Goals. This situation may result in environmental and social objectives being neglected.

### 2. Policy Incompatibility

The lack of alignment between innovation and sustainability policies emerges as a limiting factor in contributing to sustainable development (Delmas and Pekovic, 2013).

### 3. Education and Employment Issues

The decrease in the number of students studying engineering and technical fields leads to a reduction in the qualified workforce necessary for sustainable innovation and results in difficulties in converting patents into products (Schaltegger and Wagner, 2011).

These results highlight the importance of addressing innovation and sustainability policies together. Perrini et al. (2011) have stated that innovation is a crucial tool for enhancing sustainability performance. Porter and van der Linde (1995) also emphasize that innovation can enhance environmental and economic sustainability by providing a competitive advantage. However, it is essential to use resources in a manner consistent with sustainability and ecological balance to achieve long-term returns from innovation. Quality of education has a major effect on responsible consumption and production and sustainable Economic development.

### Recommendations;

#### -Policy integration

The integration of innovation and sustainability policies should be ensured in a harmonious manner. This will help balance economic growth and sustainable development goals. The contribution of innovative products to sustainability will also contribute to the success of long-term policies. It has been observed that many countries that have achieved economic development goals engage in arms exports. Developing policies that contribute to world peace and strong institutions will accelerate economic development in the long run by fostering global collaborations and enhancing international trade relations.

#### - Education and workforce development.

Education in engineering and technical fields should be encouraged, and a qualified workforce should be developed for sustainable innovation. With the increase in the young population without access to education and employment in economically developed countries, this issue becomes even more important.

#### - Promotion of social and environmental innovation.

Innovation policies should encourage initiatives that aim to solve social and environmental problems. Financial incentives and policies should be developed to increase the share of renewable energy sources in the total energy consumption. Corporates have the basic role for implementing eco-innovative strategies in line with the global sustainability perspective. Corporate governance has a significant effect for achieving global sustainability goals rather than focusing just on company sustainability. Climate action and responsible production issues can be developed by a collaborative corporate governance.

#### -Strong institutions

Companies may adopt sustainable business models to align their innovation strategies with sustainable development goals. Ensuring the preservation of clean water sources and making energy prices affordable will also contribute to increased production. Strong institutions are the main drivers for responsible production, climate action and social peace.



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