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INNOVATIVE RESOURCES AND THEIR IMPACT ON SUSTAINABLE DEVELOPMENT OF COUNTRIES: QUANTITATIVE AND POLITICAL PERSPECTIVES

RECURSOS INNOVADORES Y SU IMPACTO EN EL DESARROLLO SOSTENIBLE DE LOS PAÍSES: DESDE UNA PERSPECTIVA CUANTITATIVA Y POLÍTICA

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ABSTRACT

This study examines how innovation resources affect the management of sustainable development across countries and determines the strength and direction of the influence of innovations and innovation resources on the results of the aggregate Sustainable Development Index of countries.

Using the Sustainable Development Report 2024, which provides data on countries' performance in achieving each of the 17 United Nations Sustainable Development Goals (SDG Index), correlation-regression and variance analysis methods were applied to construct models that estimate the dependency of the aggregate Sustainable Development Index (SDI) on the outcomes of Goal 9 — Industry, Innovation, and Infrastructure — for the year 2023, as well as using cumulative data over the 24-year period from 2000 to 2023.

Drawing on data from the World Intellectual Property Organization (WIPO) and the World Bank, the analysis examined the relationship between the composite SDI and the performance in SDG 9. The regression model for 2023 accounts for approximately 72% of the variance in SDI scores. Additional models based on patent applications and R&D expenditure explain 62% and 46.9% of the variance, respectively. These results suggest that intellectual and human resources in innovation exert a stronger influence on sustainable development outcomes than financial investment alone.

Keywords: sustainability, innovation resources, patent activity, R&D expenditure, SDG 9, development management

RESUMEN

Utilizando el Informe sobre Desarrollo Sostenible 2024, que proporciona información sobre el desempeño de los países en el cumplimiento de los 17 Objetivos de Desarrollo Sostenible de las Naciones Unidas (Índice ODS), se aplicaron métodos de análisis de correlación-regresión y análisis de varianza para construir modelos que estiman la dependencia del Índice de Desarrollo Sostenible (IDS) agregado respecto de los resultados del Objetivo 9 — Industria, Innovación e Infraestructura — tanto para el año 2023 como para el periodo acumulado de 24 años comprendido entre 2000 y 2023.

A partir de datos provenientes de la Organización Mundial de la Propiedad Intelectual (OMPI) y del Banco Mundial, se analizó la relación entre el IDS compuesto y el desempeño en el ODS 9. El modelo de regresión correspondiente al año 2023 explica aproximadamente el 72 % de la varianza en los resultados del IDS. Modelos adicionales construidos en función de las solicitudes de patentes y el gasto en I+D explican el 62 % y el 46,9 % de la varianza, respectivamente. Estos resultados indican que los recursos intelectuales y humanos en innovación tienen un impacto más significativo en los resultados de sostenibilidad que la inversión financiera por sí sola.

Palabras clave: sostenibilidad, recursos de innovación, actividad de patentes, gasto en I+D, ODS 9, gestión del desarrollo

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1. INTRODUCTION

In the modern economy, issues related to the sustainable development of organizations and territories has remained highly relevant for more than a decade, ever since the United Nations General Assembly adopted the Sustainable Development Goals (SDGs) for the period up to 2030. Initially, this agenda primarily concerned countries particularly developed nations considered the main agents of environmental impact. However, over time, organizations and territories have also joined the sustainable development process as independent economic entities, implementing economic, social, and environmental policies within their territorial-geographic and resource boundaries.

At the macro-, meso-, and microeconomic levels have aimed to form systems (primarily organizational, but also sectoral, conglomerate, regional, and national systems) that are resilient to negative internal and external shocks. Among the key enabling factors, innovation, as one of the most influential factors, has a dual effect: on the one hand, it facilitates the system's transition to a new level of development through the commercialization of innovations, inventions, and know-how. Also introducing disruptions that may destabilize existing relationships among system elements, leading to fluctuations in market and production dynamics in the short and medium term.

Sustainable development is increasingly understood as a strategic, system-based process of aligning long-term economic growth, social equity, and environmental resilience. This approach emphasizes coordinated risk management and the optimal allocation of resources over time.

This dual nature of innovation is also reflected in unequal access to higher education opportunities, which directly affects social mobility and sustainable territorial development (Ruff Escobar et al., 2020). Therefore, understanding the types of resources is important to analyze the resource support for innovation activity both in Chile and globally, and to compare indicators of innovation development with the indicators and used to manage the sustainable development performance.

Also is important to understand the extent to which innovation activity resources influence the management of sustainable development, and their influence on sustainable development performance is essential.

The study aims to:

- Analyze the general patterns of influence of innovation activity on sustainable development performance.
- Identify and classify innovation resources in relation to their role in achieving SDGs.
- Evaluate the statistical relationship between innovation activity indicators and the composite SDI.

The study employs correlation-regression analysis, analysis of variance (ANOVA), as well as visual mapping methods and scatterplot diagrams.

2. THEORETICAL FRAMEWORK

The concept of sustainable development management has been internationally recognized for over three decades. Since the ratification of the 2030 Agenda, countries have not only developed national strategies but also acknowledged substantial regional disparities in access to development-enabling resources, particularly those related to innovation (Chaparro-Banegas, et al., 2024).

The concept of sustainable development of organizations and territories is formed through the integration of the approaches and notions of "development" and "potential." These constitute two interrelated frameworks that encompass the socio-economic and environmental needs of populations residing in specific territories, grounded natural-geographical, socio-economic, and other contextual conditions. The governments have increasingly incorporated these frameworks into their strategies for territorial development, environmental protection, and national policy. This is done with the aim of addressing issues such as poverty, food insecurity, climate change, and biodiversity loss, alongside the broader pursuit of the Sustainable Development Goals (SDGs).

These two approaches share several common elements, including the presence of social dialogue and mandatory negotiation among stakeholders involved in organizational and territorial development; the prioritization of inclusive participation in shaping the future of a territory; and the ecological integrity of the territory. These aspects are regarded as foundational components of both frameworks, which are based on production-regional determinants. However, the approaches also pursue divergent objectives, which may at times conflict with one another. This divergence gives rise to varying strategies, differing priority-setting policies, the emergence of diverse development institutions, and the implementation of specific measures to achieve stated goals.

Development-oriented approaches tend to focus primarily on socio-economic objectives and the revitalization of regional and sectoral economies. In contrast, capacity-oriented approaches generally prioritize biophysical and environmental objectives—firstly, by emphasizing ecological considerations and the sustainable use of natural resources, and secondly, by addressing the livelihoods and survival strategies of communities inhabiting the respective territories.

Targeted scientific and practical work in the field of sustainable development has been actively conducted since the late 1980s and early 1990s. These efforts emerged in response to escalating natural, technological, and socio-ecological-economic challenges, including environmental degradation, depletion of natural resources, climate change, natural and man-made disasters, biodiversity loss, and increased health risks for populations.

The principal international initiator has been the United Nations (UN). It was within the framework of the UN that, approximately four decades ago, the term “sustainable development” was first introduced and subsequently formalized. Since then, it has steadily entered the lexicon of professionals and, over time, the broader public.

From a theoretical standpoint, the influence of innovation on development has been framed through two classical economic perspectives. Joseph Schumpeter viewed innovation as the driving force behind economic cycles, marked by periods of growth and decline, driven by disruptive technological change. His theory anticipated several crises, including the 2008 financial collapse, and was deeply rooted in Kondratiev’s long-wave model, which emphasized the clustered and transformative nature of innovations (Ziemnowicz, 2020; Diakonova, Artyshchenko, Sysoeva, & Surovtsev, 2020).

In contrast, Israel Kirzner conceptualized innovation as a stabilizing force, arguing that entrepreneurial discovery drives markets toward equilibrium by correcting information asymmetries (Kirzner, 2009).

According to the United Nations data (United Nations, 2021b), sustainability-related innovation challenges are increasingly social and environmental, rather than purely economic. That is, disparities in life quality, unemployment, and environmental degradation often outweigh GDP-based differences. These inequalities have been exacerbated by global shocks such as the COVID-19 pandemic and ongoing geopolitical instability

The foundational definition of sustainable development stems from the Brundtland Report, which defines it as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987, p. 8). This multidimensional framework—encompassing economic, social, and environmental aspects—has become a central pillar for measuring global progress, even as some scholars critique its practical imbalance toward the economic dimension (Daly, 2018; Zakharov, Minin, & Trofimov, 2018).

Building on the foundational ideas of the 1972 report, later assessments have provided a more nuanced understanding of regional inequalities and developmental trajectories. Countries located in the Global South (primarily those in Africa) are expected to pursue development under conditions of declining birth rates. The most economically advanced Western nations (such as the United States and Western European countries) are required to address the challenges of excessive consumption and the inefficient use of available—and often abundant—resources. Asian countries (especially those in the rapidly developing Southeast Asian region) are advised to focus on technological advancement, with a strong emphasis on maintaining ecological balance through the adoption of so-called ecologically friendly technologies (Meadows, D. et al.,1975).

The economic dimensions of sustainable territorial development were examined in detail in the report Factor Four: Doubling Wealth, Halving Resource Use (E. von Weizsäcker, A. Lovins, and L. Lovins, 2000). The report argued that if the efficiency of current global resource use could be increased fourfold, and material production doubled, then the environmental burden on the planet would be reduced by half. The core message of this report is that the key issue is not the mere availability of resources within a given territory, but rather the efficiency with which those resources are utilized. Also, improving resource consumption efficiency at the territorial level is considered even more critical than increasing labor productivity in the economy, as it enables gains in profitability and growth in both national and regional income without the need for significant additional investment.

The currently implemented global agenda for sustainable development encompasses an exceptionally broad range of goals and objectives, touching upon diverse aspects of human life. Despite their comprehensive and indivisible nature, these goals and objectives can, in principle, be conceptually grouped into three tangible components: economic, social, and environmental. Consequently, the concept of sustainable development may be understood as socio-ecological-economic development, the state and progress of which can be defined, described, measured, and monitored not only through philosophical or qualitative lenses, but also by means of quantitative indicators. Both traditional and newly developed environmentally oriented metrics may serve this purpose. Sustainable functioning, in this context, refers to the performance of specific economic agents wherein a certain qualitative and quantitative balance is achieved among the economic, social, and environmental components.

Furthermore, the extensive list of global sustainable development goals underscores that addressing this issue effectively constitutes a collective responsibility shared by all states, international and regional organizations, economic actors, and civil society. The primary focus of all stakeholders should be directed toward advancing economic, social, and environmental solutions. Nevertheless, the principal role, prerogative, and accountability in this endeavor rest with national governments, as the primary agents of their respective economies. It is only through the active participation of governmental institutions and public agencies that mechanisms and instruments for sustainable development can be successfully designed, implemented, and utilized in practice.

He proposes this as a criterion for global development efficiency, in contrast to the traditional idea of balanced sustainability (Sukharev O.S., 2024). (**see Fig. 1**)

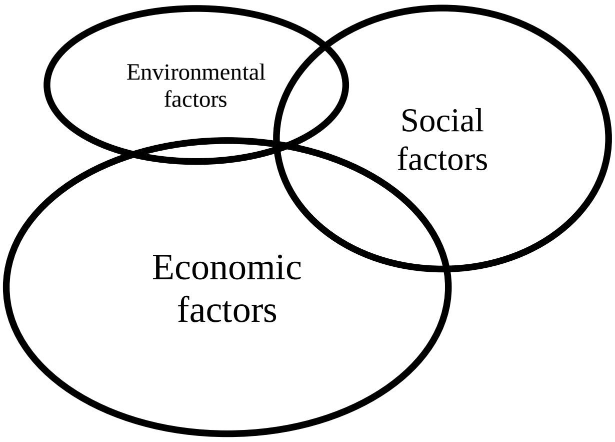


Figure 1. Actual Proportion of Factors in the Management of Sustainable Development of Organizations and Territories. Source: compiled by the authors based on data (United Nations, 2021a).

In addition to financial and human capital, sustainable development relies on institutional capacity, knowledge systems, and technological infrastructure. These resource categories shape the adaptive capabilities of organizations and territories in responding to sustainability challenges.

To address this imbalance, economic growth should be subject to stricter regulations than social development aspects or environmental protection policies (Fournier V., 2008). These alternative paradigms such as post-growth have emerged. Advocates like Wilkinson and Pickett argue for decoupling prosperity from GDP growth, emphasizing ecological innovation, equitable distribution, and resource recycling (Wilkinson R., Pickett K., 2010).

This shift is illustrated in Figure 2, which highlights the central role of innovation in transforming energy and material flows within a sustainable economic system (Hamilton, 2003).

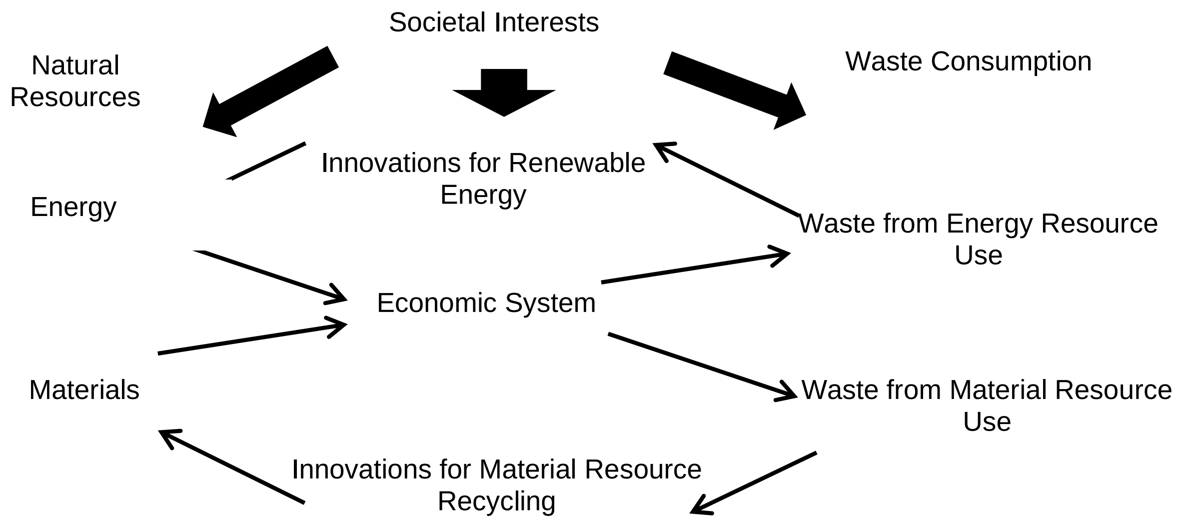


Figure 2. The Role of Innovation in the Post-Growth Economy. Source: compiled by the authors based on data (Hamilton C., 2003).

Examples of innovations associated with the post-growth economy include energy-efficient technologies, housing miniaturization solutions, the development of eco-settlements, and product simplification mechanisms aimed at minimizing failure and defect rates.

While the ideas of sustainable development and post-growth were initially supported mainly by developed countries, over time, private companies have also joined the movement by helping to organize cross-national programs such as Horizon Europe and the European Green Deal. Additionally, academic and research universities have contributed financial, material, and human resources to the process of innovation-driven sustainable development (Horbach J., 2016).

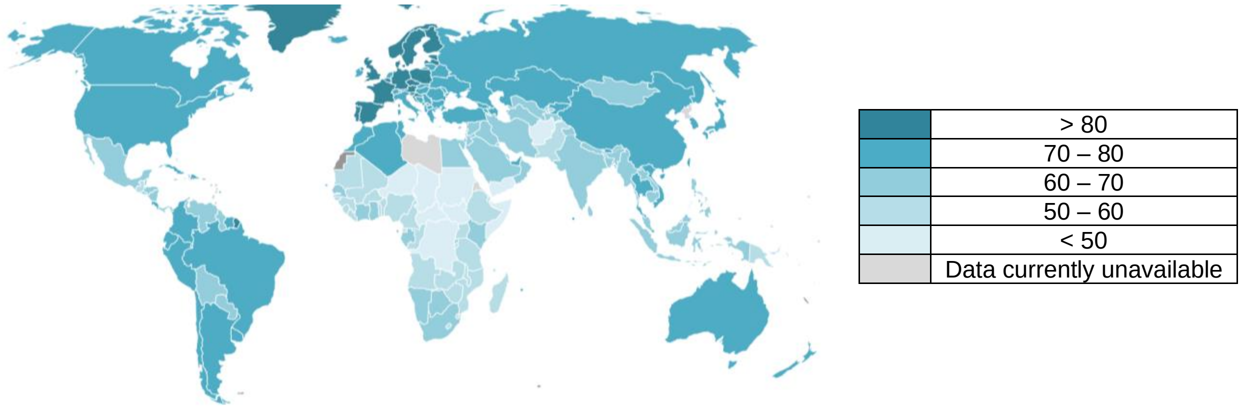
The United Nations recognizes innovation, technology, and entrepreneurship as fundamental pillars of ecological, economic, and social sustainability (Filser et al., 2019). The innovation and knowledge economies have a demonstrated positive impact on quality of life, education systems, healthcare, transportation, and industrial growth (Szopik-Depczyńska et al., 2018). Furthermore, the adoption of advanced technologies enhances the resilience of both production-technical systems and socio-environmental structures (Queiroz et al, 2022).

Nevertheless, the implementation of technological innovation is not without challenges. Innovation-driven entrepreneurship can lead to unintended negative outcomes, such as increased environmental degradation, growing disparities in the distribution of productive resources, and greater socio-economic inequality across regions (Raffer & Singer, 2002). These issues underscore the need to analyze how innovation indicators relate to the sustainability of socio-economic and environmental systems at micro-, meso-, and macro-levels.

3. MATERIALS AND METHODS

This study uses secondary data obtained from three primary sources: the Sustainable Development Report (2024a), the World Bank (2025), and the World Intellectual Property Organization (WIPO, 2025). The key dependent variable is the Composite Sustainable Development Index (SDI), measured annually for 182 countries. The main independent variables include the index for SDG 9: Industry, Innovation, and Infrastructure, national expenditure on R&D as a percentage of GDP, and the number of patent applications per million inhabitants.

After determining the strength and direction of these relationships, the study proceeds to analyze the underlying innovation-related resources, with particular attention to financial, human-capital, and information-based inputs. Using the *Data Analysis ToolPak* in Microsoft Excel, the analysis includes the construction of trendlines and the calculation of coefficient of determination (R^2) values. These models estimate the degree to which the Composite SDI depends on R&D expenditure and patent activity.
The United Nations regularly monitors progress toward sustainable development, both globally and at the country level (see Figure 3)



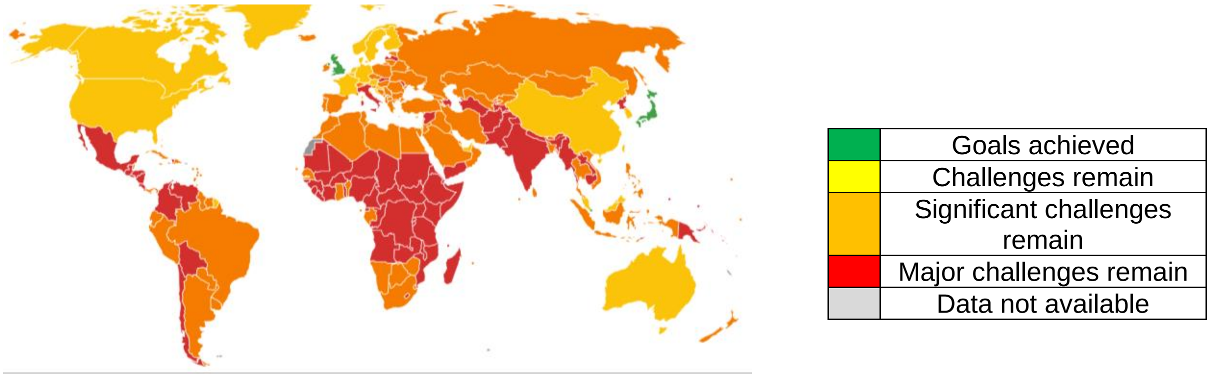
Units: Index scale from 0 to 100
Figure 3. Distribution of the Sustainable Development Goal Achievement Index Across Countries (2023)
Source: The Sustainable Development Report (United Nations,2024a).

Among the countries leading in the achievement of all 17 UN Sustainable Development Goals are the Nordic countries: Finland, Sweden, Denmark, Germany, and Norway.

The analysis of Goal 9 achievement results shows that the leading countries in the development of infrastructure, industry, and innovation are: Republic of Korea., the United States, Sweden, Switzerland, and Israel (see Figure 4)
To perform a more detailed assessment of the role of innovation in achieving sustainable development, the analysis focuses specifically on Goal 9: Industry, Innovation, and Infrastructure. This goal is unique among the 17 SDGs in explicitly identifying innovation as a critical driver of sustainable development.
Performance in SDG 9 is evaluated using multiple indicators, including:

- Access to rural road infrastructure
- Internet usage rates, including mobile broadband access
- Positions of national universities in global rankings
- Number of scientific publications
- National expenditures on R&D

Results from this analysis indicate that the leading countries in infrastructure, industry, and innovation include the Republic of Korea, the United States, Sweden, Switzerland, and Israel (see Figure 4).



Units: Index scale from 0 to 100
Figure 4. Distribution of the Index for SDG 9: Industry, Innovation, and Infrastructure Across Countries in 2023. Source: The Sustainable Development Report (United Nations,2024a).

The Sustainable Development Goals (SDGs) in this area have so far been fully achieved only in the United Kingdom, Singapore, and Japan. In most other countries around the world, there remain either significant or major challenges in meeting the goal and achieving the target indicator values.

Therefore, it is essential to analyze the extent to which performance on this specific goal influences the overall sustainable development outcomes of countries.

4. RESULTS

To initiate the empirical analysis, a scatterplot was constructed to illustrate the 2023 performance of countries on SDG 9 (*Industry, Innovation, and Infrastructure*) in relation to their corresponding scores on the Composite Sustainable Development Index (SDI).

The data used were sourced from the *Sustainable Development Report* (2024a), encompassing 182 countries and territories, including both high-income and OECD member nations (see Figure 5).

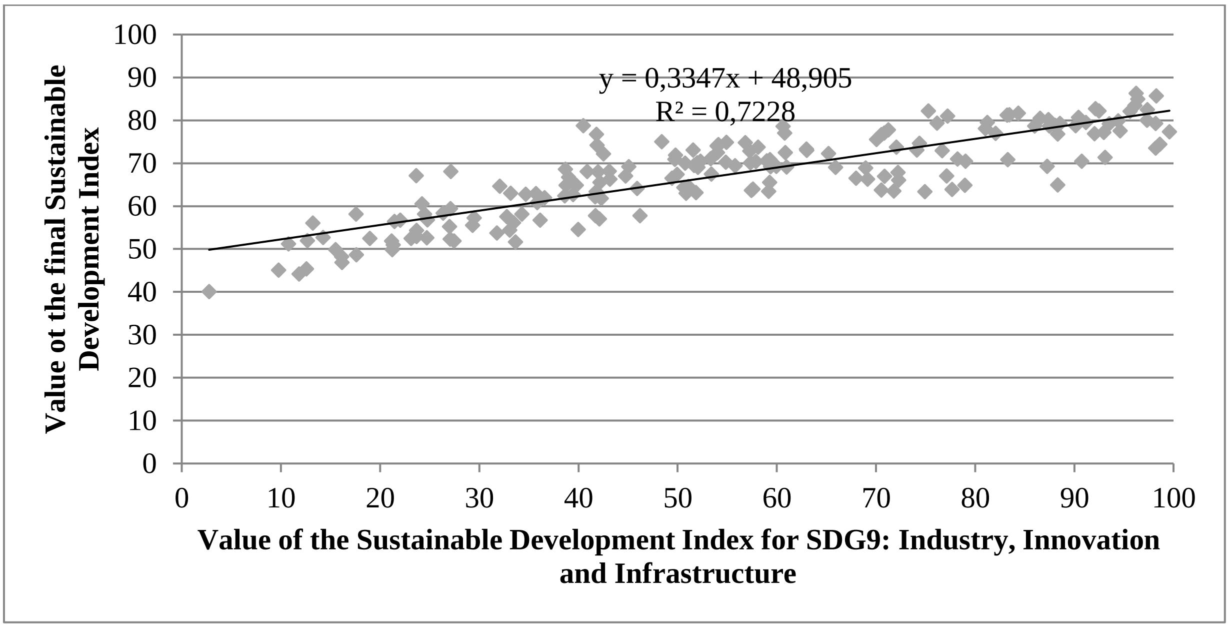


Figure 5. Distribution of Country Positions in the Composite Sustainable Development Index and the SDG 9 Index: Industry, Innovation, and Infrastructure in 2023. Source: compiled by the authors from the Sustainable Development Report (United Nations,2024a).

As illustrated in Figure 5, a positive linear relationship is evident: countries that perform better in SDG 9 also tend to achieve higher scores in the overall SDI. A trendline fitted using Microsoft Excel yielded the following linear equation: $y = 0.3347x + 48.905$, with a coefficient of determination (R^2) of 0.72.

This result indicates that approximately 72% of the variance in sustainable development outcomes can be explained by differences in SDG 9 performance. Practically speaking, each one-point increase in the SDG 9 index is associated with a 0.33-point increase in the composite SDI. These findings underscore the critical role of innovation in promoting sustainability outcomes.

To validate the robustness of this relationship, regression and variance analyses were conducted (see Table 1).

Table 1. Results of Regression and Variance Analysis of the Model Linking the 2023 Composite Sustainable Development Index to the Performance on SDG 9: Industry, Innovation, and Infrastructure. Source: compiled by the authors

Regression Statistics						
Multiple R	0,850	R Square	0,723	Observations	182	
Adjusted R Square	0,721	Standard Error	5,240			
Analysis of Variance						
	Df	SS	MS	F	Significance F	
Regression	1	12888,117	12888,117	469,429	4,8971E-52	
Residual	180	4941,877	27,455			
Total	181	17829,995				
	Coefficients	Standard Error	t-Statistic	P-Value	Lower 95%	Upper 95%
Y-Intercept	48,905	0,941	51,991	2,3712E-110	47,049	50,761
X	0,335	0,015	21,666	4,8971E-52	0,304	0,365

Note: X – Value of the Sustainable Development Index for SDG 9: Industry, Innovation, and Infrastructure; Y – Value of the composite Sustainable Development Index.

The regression model demonstrates moderate-to-high reliability, with an adjusted R^2 of 72.1%. Student's t-test values of 51.9 (for Y) and 21.6 (for X) substantially exceed the critical t-value of 1.286 (with 182 degrees of freedom at a 95% confidence level). Furthermore, the F-statistic was calculated at 469.429, well above the critical threshold of 0.88, confirming the statistical significance of the model.

While the SDG Index offers valuable cross-national comparability, its explanatory capacity can be enhanced by incorporating indicators related to institutional quality, basic needs satisfaction, and access to innovation ecosystems. These complementarity metrics allow for a more nuanced understanding of sustainability performance

To assess the model's robustness across time and regions, the analysis was extended to include cumulative data from 2000 to 2023, totaling 4,368 observations from the full UN dataset (see Figure 6).

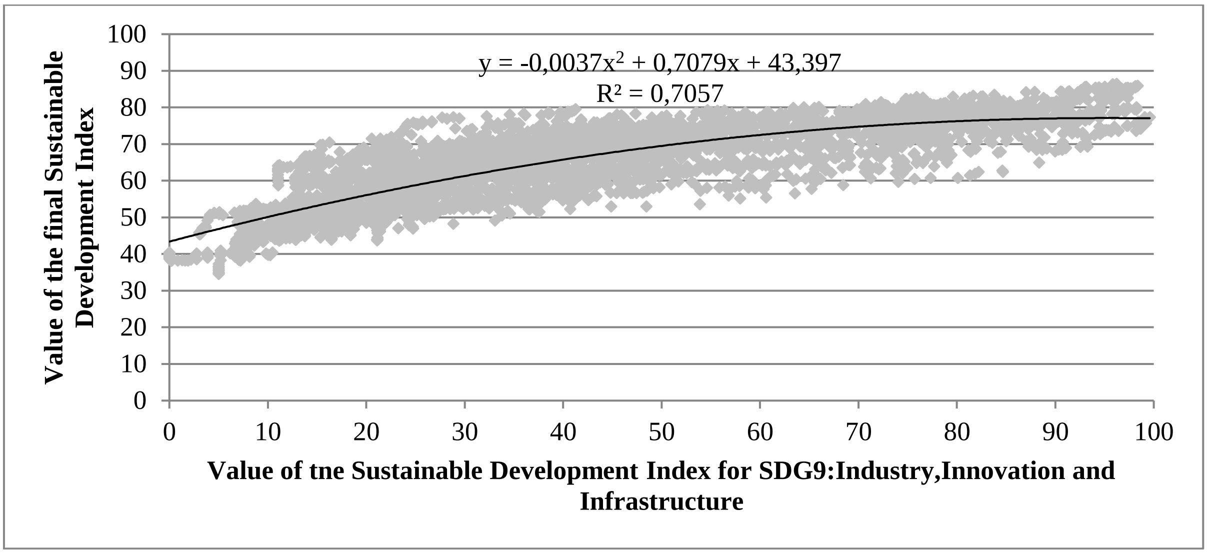


Figure 6. Distribution of Country and Territory Positions in the Composite Sustainable Development Index and the SDG 9 Index: Industry, Innovation, and Infrastructure (2000–2023). Source: compiled by the authors from the Sustainable Development Report (United Nations,2024a)

In the extended model, the predictive power of a linear regression declined slightly, yielding an R^2 of 0.66. This reduction is primarily attributed to higher variability among least-developed countries, which often exhibit inconsistent patterns in innovation-led development. To address this, a second-degree polynomial model was applied, resulting in the following equation:
$y = -0.0037x^2 + 0.7079x + 43.397$, with an improved R^2 of 0.70.

This indicates that, on a global scale, each unit increase in SDG 9 is associated with an average increase of 0.70 points in the SDI. The polynomial form captures a non-linear relationship, suggesting diminishing marginal returns to innovation at higher levels of capacity, particularly in developed countries.

A second regression and variance analysis was conducted to statistically validate this model (see Table 2).

Table 2. Results of Regression and Variance Analysis of the Model Linking the Composite Sustainable Development Index (2000–2023) to the Performance on SDG 9: Industry, Innovation, and Infrastructure. Source: compiled by the authors

Regression Statistics					
Multiple R	0,813	R Square	0,661	Observations	4368
Adjusted R Square	0,661	Standard Error	6,234		
Analysis of Variance					
	Df	SS	MS	F	Significance F
Regression	1	331055,447	331055,447	8519,449	0
Residual	4366	169657,467	38,859		
Total	4367	500712,915			

	Coefficients	Standard Error	t-Statistic	P-Value	Lower 95%	Upper 95%
Y- Intercept	49,630	0,179	277,269	0	49,279	49,981
X	0,345	0,004	92,301	0	0,338	0,353

Note: X – Value of the Sustainable Development Index for SDG 9: Industry, Innovation, and Infrastructure. Y – Value of the composite Sustainable Development Index.

At a significance level of $p = 0.05$, the critical t-value is approximately 1.96. The observed t-values of 227.269 (Y) and 92.301 (X) far exceed this threshold. Similarly, the calculated F-statistic was 8,519.449, substantially higher than the critical value of 3.845 for single-factor models.

These results confirm the model's statistical validity and reliability across a diverse sample of countries and time periods, with a moderate linear correlation ($R^2 = 0.66$) and an enhanced polynomial fit that explains up to 70% of the variation in sustainable development performance.

5. DISCUSSION

The resource provision for innovation activity can be classified into five main components: financial resources, organizational resources, material resources, information resources, and human resources. Each of these plays a distinct role in shaping sustainable development outcomes at the organizational and territorial levels.

The study examines each of these resource types in more detail and analyze several factors that influence the level of sustainable development management in organizations and territories.

As the process of sustainable development has advanced, a growing recognition has emerged among researchers and practitioners in the field that this global issue cannot be effectively addressed solely through macro-level interventions. Exclusive reliance on top-down governmental measures—whether incentivizing or regulatory in nature—has proven insufficient. The governance of sustainable development presents a degree of complexity and multidimensionality that necessitates the engagement of all economic actors and the general population, extending to individual citizens.

Within this broader system of stakeholders, commercial goods-producing enterprises occupy a particularly central position. These entities play a critical role in shaping national and regional economies, while simultaneously engaging in continuous and direct interaction with the natural environment. Such interactions often generate varying degrees of environmental degradation. As a result, the inclusion of these organizations in the formulation and operationalization of sustainable development strategies is not only essential but also structurally imperative.

An organization's internal funds consist of several components, the most critical of which is net profit. It is important to emphasize that not all profit qualifies, but only that which remains after dividends have been distributed. Profit plays a significant role in R&D activities. During the stages of theoretical inquiry and applied research, it can serve as a source of self-financing for the organization conducting the research. However, as the R&D process, its role diminishes output itself becomes the source of new profit. This profit, in turn, forms the basis for future scientific endeavors. In this sense, profit constitutes one of the foundational elements of the innovation process—essential for enhancing an organization's adaptability to changing conditions (Davydenko N. et al., 2019).

The considerations outlined above underscore the necessity of identifying and implementing strategies aimed at mitigating the negative environmental impact of commercial organizations of this type. These strategies may vary significantly, reflecting the multifunctional nature of organizational activities and depending on their specialization in the production of specific goods or services, as well as on their sectoral, organizational, and other distinctive characteristics. Each organization is inherently unique, shaped by the particularities of its production processes, management structures, and income generation models.

It is important to recognize that even organizations producing the same goods or services in equivalent volumes may differ substantially in the technologies and equipment employed, the organization of production and labor, the types and quality of raw materials and components used, the selection of resource suppliers and customer bases, the qualifications of personnel, the target markets, and the adopted production, marketing, and innovation strategies, as well as in their approaches to competition.

Consequently, the pathways toward achieving sustainable development at the micro level are rarely uniform across organizations and will be individualized and organization specific. Moreover, some organizations may prioritize the environmental dimension of sustainable development, others the social or economic dimension, and yet others a balanced combination of these components, depending on their strategic focus and operational context.

In parallel, external financial inputs, such as long-term loans or targeted innovation funds, often act as catalysts for organizations unable to rely solely on internal resources. These instruments expand the funding base and mitigate risk in the face of high-cost innovation investments.

To explore whether countries that allocate more financial resources to R&D achieve better sustainability outcomes, the analysis draws upon scatterplot data (see Figure 7).

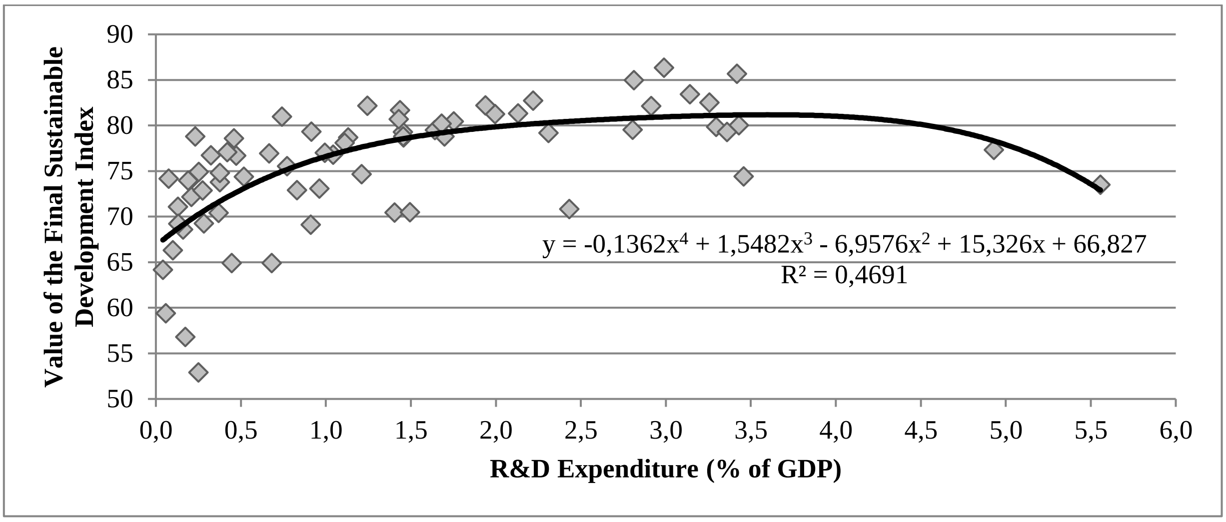


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Figure 7. Relationship Between Countries' R&D Expenditures and Their Position in the UN Composite Sustainable Development Index. Source: compiled by the authors based on data (WIPO,2025 and United Nations,2021b).

An important conclusion that can be drawn from the presented scatter plot is that financial resources alone are insufficient to guarantee improvements in sustainable development. While increased investment in science and innovation does lead to improvements in sustainability indicators, this effect is primarily observed at the initial stages. This is since many Sustainable Development Goals (SDGs) address basic human needs that can often be met through essential resources and products with low levels of technological innovation. Indeed, issues such as access to clean water, food, and electricity in the world's poorest countries are not on the cutting edge of scientific advancement but can be effectively addressed through increased investment in these sectors and the application of already-patented technologies.

Globally, most countries invest between 0.5% and 1.5% of their annual GDP to scientific research, while maintaining moderate (70–75 out of 100) or moderately high (75–80 out of 100) levels in the Sustainable Development Index. Further increases in R&D expenditure do not lead to significant improvements in countries' positions in the sustainability rankings, as the challenges faced by developed nations are no longer primarily financial. Instead, these challenges require new business models, organizational and marketing innovations, and the development of high-quality human capital suited to the knowledge economy. The mathematical model developed for this relationship $y = -0.1362x^4 + 1.5482x^3 - 6.9576x^2 + 15.326x + 66.827$ is relatively complex and provides only a modest level of approximation reliability, explaining just 46.9% of the variation in the dependent variable.

In this context, financial resources are organizational resources, which include the mechanisms for managing R&D activities. These resources are essential for the planning and execution of scientific and technological initiatives.

Material resources in innovation activities refer to the tangible expenditures related to R&D processes and outcomes, including: raw materials and supplies; consumables for production and operational needs; tools, equipment, instruments, laboratory devices, and safety gear used in R&D implementation; other non-depreciable assets; fuel, water, energy of all types, and services related to energy transformation and transmission.

The effective use of material resources presents a significant challenge for organizations, particularly in the manufacturing sector, where production defects and non-liquid raw materials, semi-finished goods, and final products are nearly inevitable. Another pressing issue is the general obsolescence of fixed production assets. As of the end of 2022, the depreciation level of fixed assets in commercial organizations exceeded 48%. In the context of ongoing trends such as import substitution, this creates substantial barriers to the adoption of innovative technologies.

Investments in science, which are by nature non-profitable and high cost, do not follow standardized rules or return frameworks. Nevertheless, the analysis suggests that the primary investor in the innovation process should be the state.

In addition to the slow pace of fixed capital renewal, organizations worldwide face obstacles in accessing new technologies, their corresponding markets, and digital infrastructure. All these factors slow down innovation at the organizational level and, more broadly, have a negative impact on sustainable development outcomes.

In global business practice, organizations that have a clear understanding of their informational and intellectual capacities tend to be more competitive. These capabilities are manifested through patents, databases, and access to information and communication technologies (ICTs).

Among the global leaders in innovation-driven development are the so-called Asian Tigers—notably Republic of Korea (with a clear lead), Japan, and China—as well as the Nordic and Northern European countries, including Sweden, Finland, Denmark, Germany, and the Netherlands. In these countries, the presence of intellectual resources, as reflected in patent activity, has a significantly greater effect on sustainable development levels than financial investment alone (**see Figure 8).**

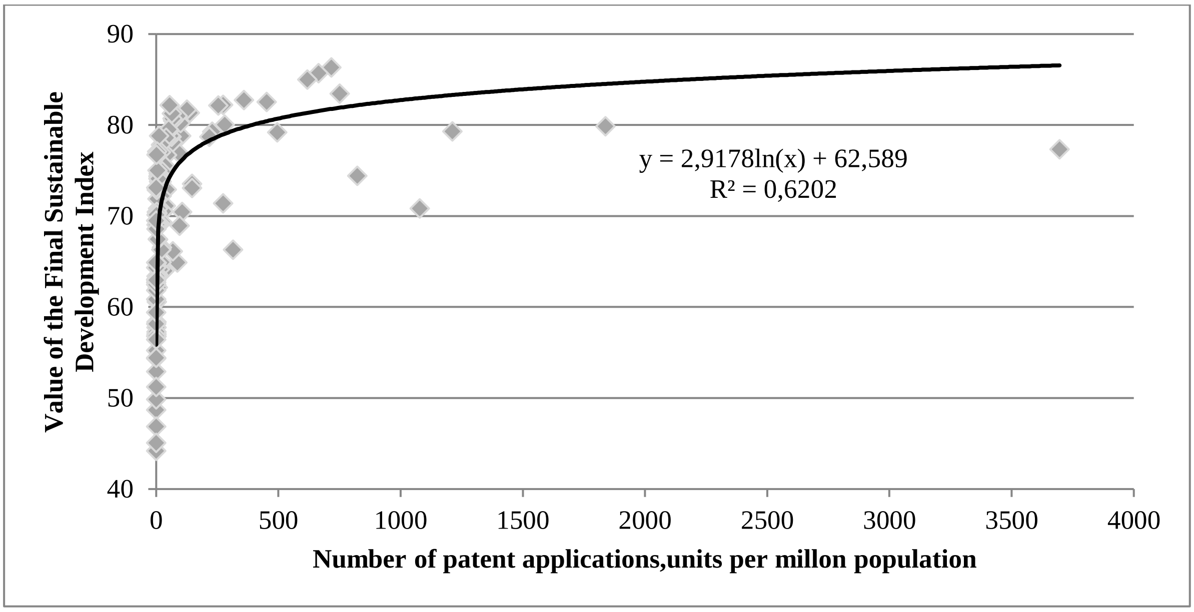

Figure 8. Relationship between the number of patent applications by country and their position in the overall UN Sustainable Development Index. Source: compiled by the authors based on data (WIPO,2025 and United Nations,2021b).

If the increase in spending on science and innovation explains only 46% of the growth in the final Sustainable Development Index, then in this model, patent activity accounts for approximately 62% of the index's growth.

Notably, unlike the previous model, this one does not exhibit a clear decline or saturation effect in the final index as the explanatory variable increases. The resulting equation takes the form $y = 2.9178\ln(x) + 62.589$, with an approximation reliability of 0.62. This suggests that investment in intellectual resources have a more pronounced positive effect than financial investment alone, particularly when the latter lacks corresponding informational support and intellectual property protection.

In less-developed regions, the impact of innovation on sustainability is contingent on contextual factors, particularly the alignment of innovation policies with basic social needs and the presence of enabling institutions. Therefore, patent output and R&D investment may yield limited returns without supportive governance frameworks.

Undoubtedly, these factors rarely operate in complete isolation. It is difficult to envision patent development and filing activities without financial backing, or scientific investment devoid of subsequent intellectual property protection efforts. Accordingly, the authors posit that in combination, these factors are likely to produce a synergistic effect, increasing their overall impact on the final Sustainable Development Index.

The availability and quality of human capital are largely dependent on equitable access to higher education, which plays a pivotal role in fostering social mobility and territorial cohesion, as highlighted in recent studies (Ruff Escobar et al., 2020). It is crucial, however, to direct human efforts appropriately. This is where organizational resources play a vital role: the system of managerial decision-making within the organization and its network of relationships with suppliers, end-users, and other actors in the R&D chain, all of whom contribute to advancing a given idea toward the final output. The success of these processes and the resulting product will shape the organization's reputational resource—that is, how its research and development efforts are perceived in terms of their effectiveness and real-world applicability. This, in turn, impacts the organization's income and influences its ongoing operations, all of which are sustained by the full range of resources examined in this study.

6. CONCLUSION

The findings of this study allow us to draw several key conclusions:

Overall, innovation, science, and technology exert a positive influence on the level of sustainable development across organizations and territories. The derived mathematical model for 182 countries (serving as control points), expressed as $y = 0.3347x + 48.905$, accounts approximately 72% of the variation in the dependent variable y (the final Sustainable Development Index), explained by changes in the independent variable x (achievement level of Sustainable Development Goal 9: Industry, Innovation, and Infrastructure) in the year 2023. When expanding the sample size to include 4,368 control points covering the period from 2000 to 2023 across all observed countries, the model's explanatory power slightly decreases to 70%, with the updated specification $y = -0.0037x^2 + 0.7079x + 43.397$. This decrease is attributed to higher variability in the endogenous variable among the least developed countries. In both models, a “low-base effect” is observed: in developing and underdeveloped countries with initially low Sustainable Development Index scores, progress on Goal 9 leads to substantial improvements in the overall index. In contrast, for developed countries, further growth in both the composite index and Goal 9 achievement tends to decelerate, reflecting diminishing marginal returns to innovation-related investments.

Although financial resources for innovation are often perceived as a strategic priority for fostering sustainable development, they do not appear to constitute the primary determinant of competitiveness or growth, either at the national level or within individual organizations. The increase in R&D expenditures explains only around 46% of the variance in the composite Sustainable Development Index. The corresponding model, $y = -0.1362x^4 + 1.5482x^3 - 6.9576x^2 + 15.326x + 66.827$, reveals substantial variability in the dependent variable y (final index) in response to increases in the independent variable x (R&D expenditure as a percentage of GDP). These findings align with empirical evidence from innovation policy at national, sectoral, and organizational levels, which suggests that financial investment alone is insufficient to drive sustainable development. Rather, such investments are most effective when complemented by other innovation-enabling resources: informational (e.g., access to intellectual property, technologies, databases, and markets), material (e.g., access to raw materials, capacity to renew capital assets), and human (e.g., knowledge, skills, qualifications, and experience).

Among these, informational resources stand out as having a significantly greater impact on sustainable development outcomes. The developed model y = 2.9178ln(x) + 62.589 explains 62% of the variation in the dependent variable y (composite Sustainable Development Index) as a function of the independent variable x (number of patent applications per million inhabitants). Informational resources are closely linked to human capital, as the creation of intellectual property requires advanced expertise and substantial professional experience. As such, intellectual and human capital should be regarded as the core drivers of sustainable development for both organizations and nations.

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