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EVALUATING THE ROLE OF SDG 9 IN ECONOMIC GROWTH AND ENVIRONMENTAL SUSTAINABILITY: A QUANTITATIVE ANALYSIS ACROSS THE EUROPEAN UNION

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Abstract:
The urgency of sustainable development resonates globally, promoting a balanced interaction between human advancement and environmental stewardship through the United Nations Sustainable Development Goals (SDGs). Of these goals, SDG 9 which emphasizes "Industry, Innovation, and Infrastructure" is vital for catalyzing economic growth and enhancing social and environmental sustainability. This research centers on SDG 9 within the European Union, aiming to elucidate its impact on sustainable development through rigorous analysis of industry, innovation, and infrastructure developments. This study employs comprehensive quantitative methodologies to assess the implications of SDG 9. Utilizing data from reputable international organizations, we conducted detailed statistical analyses using IBM SPSS Statistics to explore correlations and regressions among key performance indicators of SDG 9. The findings reveal a positive correlation between innovative activities, particularly in R&D, and economic outputs in sectors aligned with environmental goods and services. Regression analyses demonstrated a significant positive trend in the global SDG Index Score, particularly within SDG 9, indicating substantial progress from 2000 to 2022. This growth highlights the effectiveness of targeted measures in industry and infrastructure that have outpaced broader SDG achievements, suggesting that focused innovations and infrastructural investments can accelerate sustainable development. The EU's experience suggests that leveraging technology and innovation within these areas substantively contributes to broader sustainable development objectives, offering valuable insights for global policy strategies. This study underscores the necessity of integrating SDG 9 within a multifaceted approach to achieving comprehensive sustainability, enhancing policy implications that may guide future international efforts in sustainable development.

Key words: Sustainable development, industry, innovation, infrastructure, SDGs, competitive advantage.

JEL classification: O32, O44, O52, M21.

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1. INTRODUCTION

The sustainable development imperative has a global echo, underpinning the collective effort to ensure a balanced coexistence between human progress and environmental management. At the heart of this effort are the United Nations SDGs which encapsulate the holistic nature of sustainable development by addressing the interrelated aspects of economic development, social integration, and environmental conservation.

The importance of sustainable development lies in its capacity to create a framework that balances multiple, often competing objectives. The interplay between industrialization, innovation, and infrastructure and their cumulative impact on sustainable development remains a critical area of focus within the European Union, particularly as these elements are integral to the achievement of SDG 9. This goal, which prioritizes "Industry, Innovation, and Infrastructure," is pivotal not only for catalysing economic growth and fostering employment but also for its broader implications on environmental and social sustainability. The emphasis on SDG 9 arises from its potential to transform economies through technological advancements, enhanced connectivity, and improved industrial capacity, thereby facilitating a shift towards more sustainable and resilient societies. Infrastructure under SDG-9 principally relies on environmental considerations and worldwide commitments, being influenced by scientific research and innovation [1]. SDG 9 is based on robust and sustainable innovation, along with infrastructure that supports accessible and fair availability for all, promoting equitable and enduring industrial development [2]. The EU's strategic emphasis

on innovation and sustainable industrial practices as facilitated by SDG 9 underlines a key approach to sustainable development: leveraging technological and scientific advancements to create sustainable solutions that address urgent environmental issues while fostering economic growth. This approach not only supports the particular objectives of SDG 9 but also contributes to the broader objectives of the SDGs, such as reducing inequality (SDG 10), ensuring resilient urban areas and communities (SDG 11), and fostering sustainable consumption and production practices (SDG 12). Therefore, the integration of SDG 9 within the broader framework of the SDGs in the EU exemplifies a model of development that other regions and countries can emulate. It underscores the necessity of a multi-faceted strategy in achieving sustainable development, one that harnesses the synergies between economic development, environmental sustainability, and social equity. This research seeks to enhance our comprehension of these dynamics, providing policy recommendations that can help enhance the efficacy of the SDGs globally, ensuring a sustainable future for all.

Recent studies have concentrated on developing a global SDG index to encapsulate each country's performance in achieving the goals, acknowledging that certain goals may conflict with others [3]. The EU holds a robust initial stance on sustainable growth and, in collaboration with its member states, is dedicated to spearheading the UN Program by 2030 [4]. An examination of the initiatives targeted by the EU in the past, through the lens of sustainability, climate action, and poverty reduction, reveals substantial progress made by the EU in these critical domains [5]. Within the framework of the European Union, the significance of SDG 9 is underscored by its direct impact on various economic and environmental outcomes. For instance, industrialization is not only a driver of economic prosperity and job creation but also a sector under scrutiny for its environmental footprint, necessitating a balance between economic growth and environmental stewardship. The EU's experience illustrates how sustainable industrial practices, supported by innovation and robust infrastructure, can lead to improved environmental outcomes while boosting economic performance. Furthermore, the analytical focus on the correlation between R&D investments and sectoral growth within the EU provides a nuanced understanding of how strategic investments in innovation fuel economic sectors, particularly those related to environmental goods and services. This relationship is crucial for policy formulations aimed at achieving the dual objectives of economic growth and environmental sustainability. The systematic examination of these dynamics, facilitated by empirical data from EU countries, offers valuable insights into the effectiveness of current policies and the need for targeted strategies to enhance the impact of SDG 9.

2. MATERIALS AND METHODS

The research methodology employed in this scientific article entails a robust quantitative analysis to elucidate the implications of SDG 9 focused on sustainable development, particularly within the European Union. The methods used include a range of statistical tools and data sources designed to measure and analyse key performance indicators relevant to SDG 9. The primary materials include comprehensive datasets sourced from reliable reports such as those provided by international organizations and development agencies. These datasets offer extensive coverage of various metrics related to industry, innovation, and infrastructure across multiple countries. As research methods in this article, we use descriptive statistics elements like mean, median, range, standard deviation to describe the distribution of data and central trends of ODD scores in different countries. IBM SPSS Statistics is used for detailed statistical analysis and to process the correlation dependencies among the SDG indicators and regression analysis to model the relationships between variables. Pearson correlation coefficients are calculated to examine the linear relationships between different indicators related to SDG 9, like R&D personnel, gross domestic expenditure on R&D, and patent applications. This analysis helps in identifying the strength and direction of associations between these variables. Application of linear regression models to quantify the relationship between variables, providing a formula that describes these relationships and an R2 value to explain the variability in one variable accounted for by the other.

Employing graphical representations such as bar charts and scatter plots to visually summarize the findings and trends in the data. These visual tools aid in better understanding and communication of the statistical results. The combined use of empirical data, advanced statistical methodologies, and comprehensive analysis techniques underlines the indispensable role of SDG 9 in advancing sustainable industrialization, encouraging innovation, and establishing durable infrastructure. The findings derived from the European Union's experience emphasize the need for targeted policies and investments to enhance these areas, which are essential for sustainable development and economic growth. By scientifically analyzing the intricate relationships between various SDG 9 indicators, this research contributes significantly to the understanding of how integrated efforts in industry, innovation, and infrastructure can lead to broader socio-economic benefits and environmental sustainability.

3. RESULTS

SDG 9 centered on "Industry, Innovation, and Infrastructure" is indispensable for achieving economic growth and sustainable development. The importance of SDG 9 results from its strong impact on the subsequent pylons (Figure no. 1):

Figure no. 1. The main pylons of SDG 9 importance and its strong impact on sustainable development

Source: Own elaboration using data available in the Report [6]

First at all, industrialization drives economic growth, significantly enhances job creation, and increases income. By developing their industries, countries can diversify their economies and reduce their dependence on primary commodities.

Opportunities for decent employment are imperative for fostering sustainable growth and economic well-being. The significance of equitable remuneration, secure employment, safe working conditions is fundamental in cultivating a more equitable and efficient industrial environment [7]. Swift industrial growth is the principal catalyst for environmental deterioration. Industrial activities have precipitated an increase in pollution, depletion of habitats, and utilization of resources. This industrial expansion often leads to significant alterations in natural landscapes and ecosystems, contributing to biodiversity loss and the disruption of ecological balance [8]. SDG 9 also focuses on promoting inclusive and sustainable industrialization. Supporting small-scale industries and value addition are significant components that can drive economic growth and job creation, particularly in developing countries.

Innovation and technological progress are essential for identifying enduring solutions to economic and environmental challenges, such as creating new employment opportunities and

enhancing energy efficiency. SDG 9 emphasizes enhancing technological capabilities and encouraging innovation, which are crucial for long-term competitiveness. By fostering innovation in industries and infrastructure, we can promote more sustainable and environmentally friendly practices. This includes advances in clean technology, improved environmental standards, and better management of resources. SDG 9 also promotes the creation of high-quality, dependable, sustainable, and robust infrastructure, encompassing both regional and cross-border structures, to bolster economic growth and human welfare. This helps in achieving greater connectivity and integration, which are vital for global trade and cooperation.

The next graph provided in Figure no. 2 represents the evolution of the global SDG Index Score and Goal 9 Score between 2000 and 2022, representing the annual progress of the global SDG Index and specifically SDG 9, which focuses on industry, innovation, and infrastructure, over a span of 22 years.

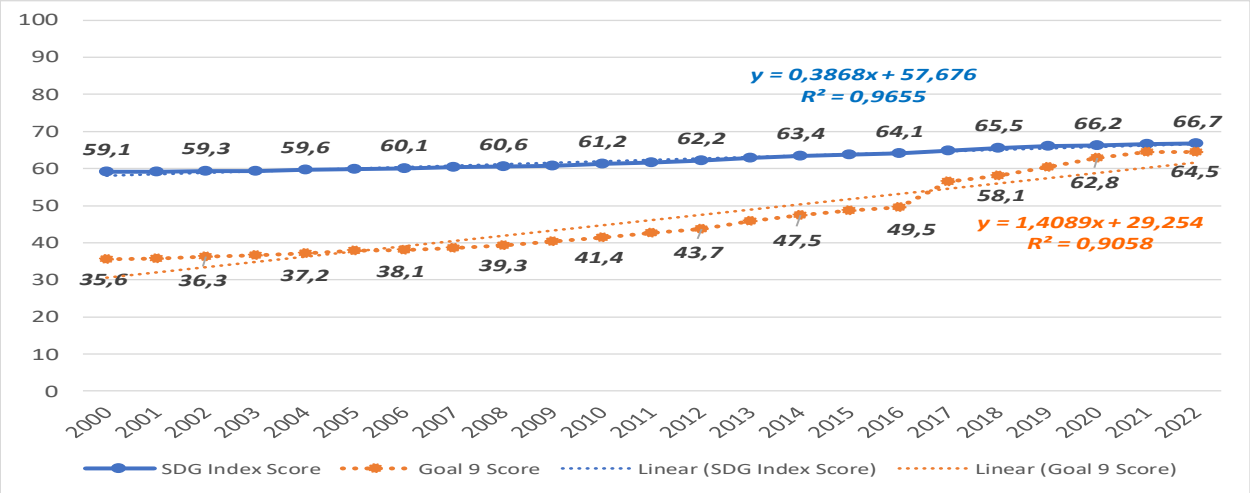

Figure no. 2. Evolution of the global SDG Index Score and Goal 9 Score between 2000 and 2022

Source: Own elaboration using data available in the Report [6]

The line representing the global SDG Index Score shows a gradual and consistent increase from 2000 to 2022, starting at approximately 59.1 and rising to about 66.7. This upward trend is modeled with a linear regression line, denoted through the formula y=0.3868x+57.676, where x represents the year. The coefficient of determination (R2) for this regression is 0.9655, indicating a very high level of model fit, suggesting that the linear model explains approximately 96.55% of the variability in the SDG Index Score.

The line illustrating the Score for SDG 9 also shows a progressive increase from about 35.6 in 2000 to 64.5 in 2022. Its linear trend line is given by y=1.4089x+29.254 with an (R2) of 0.9058. This also indicates a strong linear relationship, explaining about 90.58% of the variation in the SDG 9 Score. Both the overall SDG Index and the SDG 9 Score have shown consistent year-over-year improvements. This implies effective global efforts towards achieving the targets set under the Sustainable Development Goals framework, particularly in the domains covered by SDG. The slope of the SDG 9 Score trend line is significantly steeper than that of the overall SDG Index Score. The sharper increase in the SDG 9 Score compared to the overall SDG Index might indicate that more focused or effective measures have been implemented in the areas of industry, innovation, and infrastructure than in other SDG areas. This could be due to technological advancements, increased investments in infrastructure, or heightened international cooperation. The strong performance of SDG 9 underscores its pivotal role in not only boosting economic growth and development but also in facilitating broader achievements across other SDGs, given its influence on infrastructure, innovation, and industrial capabilities.

The data visually highlights the positive trajectory in global efforts towards sustainable development, with notable strides in enhancing industry, innovation, and infrastructure. The high coefficient of determination values for both trends affirm robust linear relationships, indicating predictable growth patterns based on past trends, which can be crucial for policy planning and resource allocation in future sustainability initiatives.

SDG 9 concentrates on developing resilient infrastructure, fostering inclusive and enduring industrialization, and fostering innovation. To demonstrate the crucial link between innovation, intellectual property (IP), sustainability, and corporate longevity, attributes of century-old companies are compared with those of newer multinationals that depend on IP-intensive business models [9].

The following figure shows the distribution of the SDG Goal 9 SDG index score across 162 countries in 2022 and illustrates the disparity in performance of different countries on SDG 9, which focuses on industry, innovation and infrastructure. The data, extracted from the Report and represented as a bar chart, ranks countries according to their SDG index score for Goal 9.

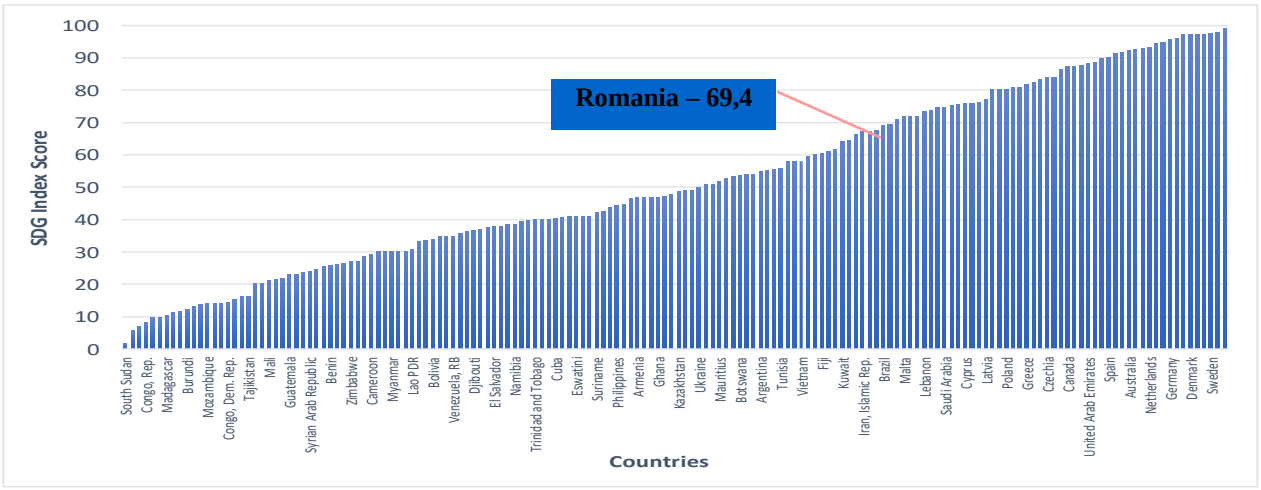

Figure no. 3. Distribution of the Goal 9 SDG Index Score in 162 countries in 2022
Source: Own elaboration using data available in the Report [6]

The distribution of scores is not uniform. There is a visible trend of more countries clustering towards higher scores, especially those above 50, indicating a general global trend toward improvement in areas pertinent to SDG 9. The steepness of the graph's rise towards the higher-scoring countries suggests that while many countries perform well, a significant number still lag considerably behind. The graph underscores the existing disparities in economic development, technological advancement, and infrastructure across the globe. Countries with higher scores likely benefit from more robust industrial sectors, advanced technological capabilities, and better infrastructure, which in turn may support broader economic and social advancements As research by other scientists confirms, the same countries have been at the top for several years, while other countries are making different progress [10]. Also, the research findings reveal a pronounced spatial disparity among European nations concerning sustainable development indicators: Western and Northern European countries rank higher, whereas Southern and Eastern European countries appear lower in the rankings [11]. The data highlights the need for targeted policies and investments in countries with lower scores to boost their industrial and infrastructural sectors. International aid and cooperation might be necessary to elevate the scores of these nations. The variance in scores also reflects broader global inequalities. Countries with lower scores may struggle with issues like poverty, limited access to education, and inadequate health care, all of which can hinder the ability to improve industry and infrastructure.

The statistics suggest a world where there is a significant disparity in achievements related to SDG Objective 9 (Industry, Innovation, and Infrastructure). A majority of countries score below

75.35, with very few reaching scores close to the maximum. The presence of a mode at a high score (80.30) and a lower median indicates a few countries are significantly outperforming others. The median score is 48.15, suggesting that half of the countries have an index score below 48.15 and the other half above this score. The median being lower than the mean suggests a right-skewed distribution. The most frequently occurring score among the countries is 80.30. This could indicate a clustering of countries around this score, but given it is substantially higher than both the mean and median, it might reflect a specific subgroup of countries performing exceptionally well in this regard.

Table no. 1. Indicators characterizing the distribution of the Objective 9 score in 162 countries in 2022 processed in IBM SPSS Statistics

N	Valid	162
	Missing	0
Mean		51.8457
Median		48.1500
Mode		80.30
Std. Deviation		26.66030
Variance		710.771
Skewness		.145

Std. Error of Skewness		.191
Range		97.40
Minimum		1.70
Maximum		99.10
Percentiles	25	30.2000
	50	48.1500
	75	75.3500

Source: Own elaboration using data available in the Report [6]

The range (97.40) tells us that the difference between the highest (99.10) and lowest (1.70) scores is vast, highlighting extreme variations in development levels related to SDG Objective 9. The Standard Deviation value (26.66030) shows there is a considerable spread in the SDG scores among the countries, indicating significant disparity in how different nations perform regarding Objective 9. The skewness of .145 suggests a slight skew to the right, which means there are more countries scoring below the mean, with fewer countries achieving very high scores.

This detailed analysis highlights the challenges and disparities faced globally in achieving the SDG Objective 9. It calls for targeted interventions to help lower-scoring countries improve their infrastructure and innovation capacities, which is essential for sustainable growth.

Within the nations of the European Union there is a group of indicators that measure and characterize the achievement of Goal 9 of the SDGs called "Industry, Innovation and Infrastructure" [12] of which the greatest focus on industry and innovation are the indicators shown in Figure no. 4.

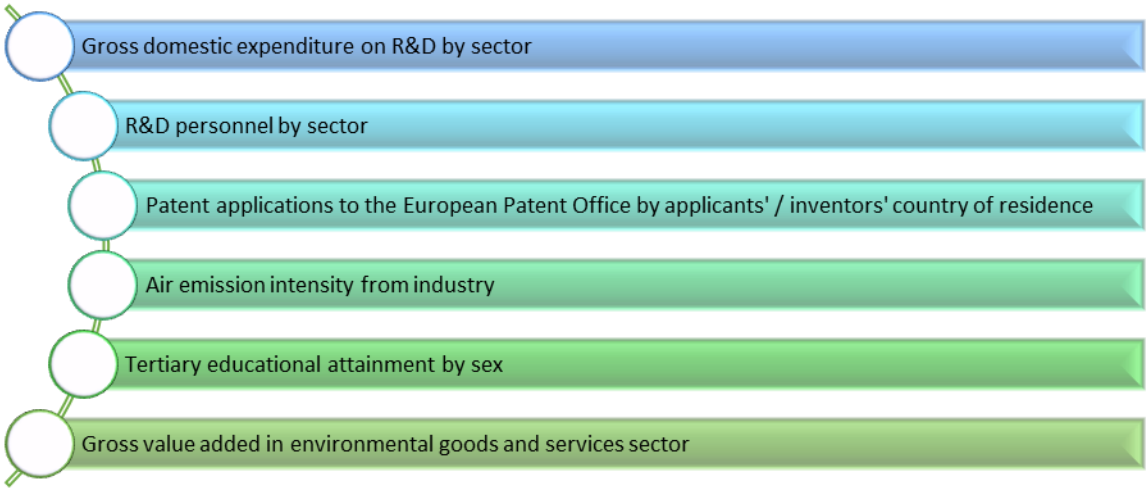

Figure no. 4. Indicators with the greatest focus on industry and innovation used to measure and characterise the achievement of SDG Goal 9 in EU countries

Source: Own elaboration using information available on [12]

This figure effectively outlines the diverse indicators used to track the advancement towards achieving SDG 9 in EU countries. The eco-innovation index from the European Commission indicates that between 2013 and 2022, there has been an enhancement in the performance of EU countries regarding eco-innovation [13]. These indicators collectively provide a comprehensive picture of how well these countries are fostering industrial growth, promoting innovative practices, and ensuring sustainable infrastructure development. Each indicator not only gauges progress in specific areas but also highlights where there may be room for policy improvements and increased investment.

Table no. 2 explains correlation dependence between indicators with the greatest focus on industry and innovation used to measure and characterize the achievement of SDG Goal 9 in EU countries. This analysis is based on data from 27 EU countries for the year 2022 and was processed using IBM SPSS Statistics.

Table no. 2. Correlation dependence between indicators with the greatest focus on industry and innovation used to measure and characterise the achievement of SDG Goal 9 in EU countries, based on 27 EU countries (data specific to 2022).

		RD_personnel_by_sector	Gross_domestic_expenditure_on_RD_by_sector	Patent_applications_to_the_European_Patent_Office	Air_emission_intensity_from_industry	Gross_value_added_in_environmental_goods_and_services_sector	High_speed_internet_coverage_by_type_of_area	Tertiary_educational_attainment_by_sex
RD_personnel_by_sector	Pearson Correlation	1	.886**	.373	-.355	.277	-.045	.292
	Sig. (2-tailed)		.000	.056	.075	.163	.823	.139
	N	27	27	27	26	27	27	27
Gross_domestic_expenditure_on_RD_by_sector	Pearson Correlation	.886**	1	.498**	-.313	.367	-.134	.097
	Sig. (2-tailed)	.000		.008	.120	.060	.507	.630
	N	27	27	27	26	27	27	27
Patent_applications_to_the_European_Patent_Office	Pearson Correlation	.373	.498**	1	-.268	.827**	-.047	-.031
	Sig. (2-tailed)	.056	.008		.186	.000	.817	.878
	N	27	27	27	26	27	27	27
Air_emission_intensity_from_industry	Pearson Correlation	-.355	-.313	-.268	1	-.252	.208	-.186
	Sig. (2-tailed)	.075	.120	.186		.214	.308	.362
	N	26	26	26	26	26	26	26
Gross_value_added_in_environmental_goods_and_services_sector	Pearson Correlation	.277	.367	.827**	-.252	1	-.153	-.126
	Sig. (2-tailed)	.163	.060	.000	.214		.445	.531
	N	27	27	27	26	27	27	27
High_speed_internet_coverage_by_type_of_area	Pearson Correlation	-.045	-.134	-.047	.208	-.153	1	.209
	Sig. (2-tailed)	.823	.507	.817	.308	.445		.295
	N	27	27	27	26	27	27	27
Tertiary_educational_attainment_by_sex	Pearson Correlation	.292	.097	-.031	-.186	-.126	.209	1
	Sig. (2-tailed)	.139	.630	.878	.362	.531	.295	
	N	27	27	27	26	27	27	27

**. Correlation is significant at the 0.01 level (2-tailed).

Source: Own elaboration using data available on https://ec.europa.eu/eurostat processed in IBM SPSS Statistics

The table includes a variety of indicators such as R&D personnel by sector, sectoral gross domestic expenditure on R&D, patent filings at the European Patent Office, industry's air emission rates, and others. These indicators are the most important for measuring aspects of development of industry, innovation, and infrastructure within the EU. Each cell contains a Pearson correlation coefficient that quantifies the linear relationship between two indicators. A positive coefficient indicates a direct correlation, where a rise in one indicator correlates with an increase in the other, and the reverse is also true for negative coefficients. Below each coefficient, a significance value (p-value) is given, assessing the probability that the observed correlation occurs by chance. Typically, a p-value below 0.05 (as indicated by asterisks in the table) suggests that the correlation is statistically significant and likely reflects a true association rather than random variability.

This correlation matrix provides valuable insights into how different facets of industry, innovation, and infrastructure are interlinked within the EU. Understanding these relationships helps in identifying key areas for policy intervention, investment, and research to effectively drive progress towards achieving SDG 9. Such analyses also underline the complexity of the interactions between different socio-economic factors and their collective impact on sustainable development goals.

The highest level of correlation dependence intensity is found between R&D staff by sector and total sectoral spending on R&D, with a Pearson coefficient for this group of indicators of 0.886. The following figure graphically expresses the correlation dependence between these two indicators based on 27 EU countries (data specific to 2022).

The linear regression line helps to visualize the trend in the relationship between the two variables across the dataset. Regression Equation y=1.4564x−0.332 describes the linear relationship determined by the regression analysis, where x is the percentage R&D staff by sector and y is the gross domestic expenditure on R&D by sector as a percentage of GDP.

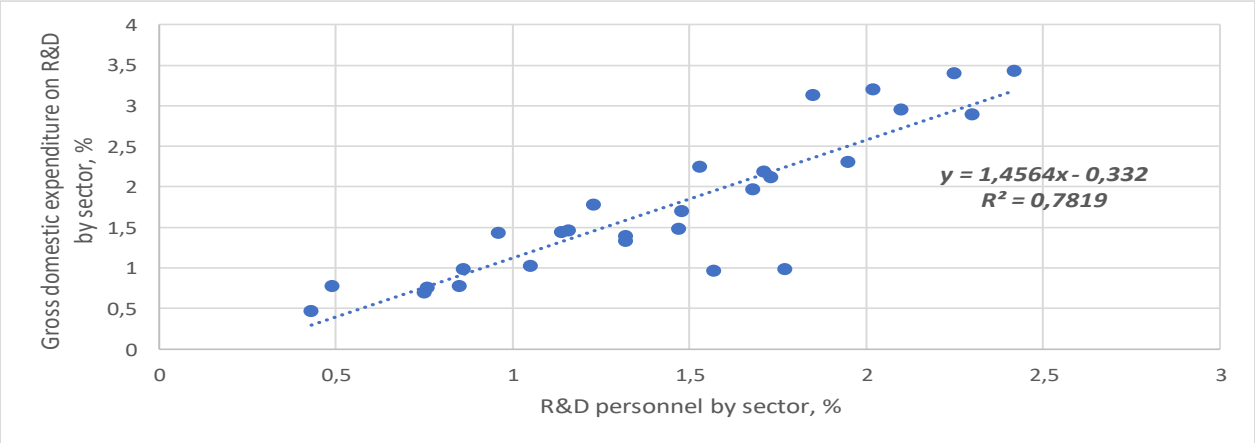

Figure no. 5. Correlation dependence between R&D staff by sector and Gross domestic expenditure on R&D by sector based on 27 EU countries (data specific to 2022)

Source: Own elaboration using data available on [12]

The slope of 1.4564 suggests that for every 1% increase in R&D personnel, there is an approximate 1.4564% increase in R&D expenditure. The Coefficient of Determination (R^2) value of 0.7819 suggests that about 78.19% of the variability in R&D spending can be accounted for by the variation in R&D personnel percentages across these countries. This high R2 value signifies a strong correlation and suggests that the model fits the data well.

The scatter plot and the derived regression analysis reveal a significant positive relationship between the percentage of R&D staff and the gross domestic expenditure on R&D. The positive slope of the regression line indicates that an increase in the proportion of personnel dedicated to R&D activities is associated with an increase in financial investment in R&D across different sectors. This relationship underscores the importance of human resources in driving R&D activities: more R&D personnel not only reflect increased capacity for research and innovation but also necessitate and justify higher expenditure to support these activities.

Another pair of indicators with the high level of correlation dependence intensity are the patent filings at the European Patent Office and the added economic value in the environmental goods and services sector, this dependence is shown in the figure no. 6.

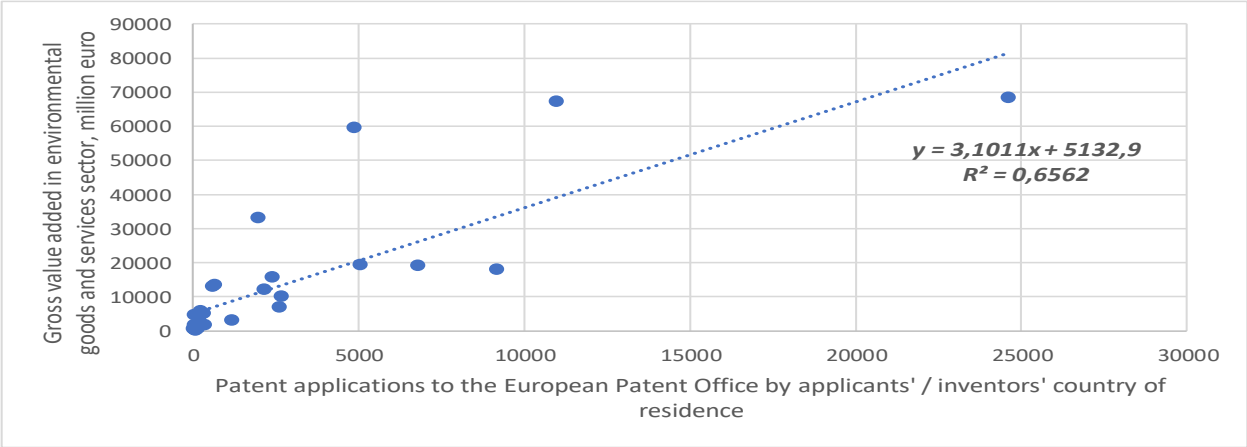

Figure no. 6. Relationship between the patent filings at the European Patent Office by applicants' / inventors' country of residence and added economic value in the in environmental goods and services sector based on 27 EU countries (data specific to 2022)

Source: Own elaboration using data available on [12]

Figure no. 6, as described, presents a scatter plot illustrating the relationship between the number of patent filings at the European Patent Office by the country of residence of applicants or inventors and the economic contribution of the environmental goods and services sector across 27 EU countries in 2022.

The regression line represented throw the equation y=3.1011x+5132.9 describes the regression line where x represents the number of patent applications, and y is the gross value added. The regression coefficient of 3.1011 suggests that for every additional patent application, there is an average increase of approximately 3101.1 euros in the economic contribution of the environmental goods and services sector. Thus, the positive slope of the regression line indicates a positive correlation between patent applications and economic output in the environmental sector. This implies that increased innovation, as measured by patents, is associated with higher economic contributions from this sector. The R2 coefficient, standing at 0.6562, elucidates that approximately 65.62% of the fluctuation in gross value added within the environmental goods and services sector is attributable to variations in patent application numbers. This suggests a substantial, though not complete, predictive power of patent applications on economic output in these sectors. This strong correlation has been highlighted in various papers by researchers [14]. The data underline the argument that innovation, particularly in the environmental sector, is a key driver of economic value. Innovation serves as a fundamental pillar for economic growth, enhancing productivity and competitiveness. Expansion in the industrial sector was undertaken to bolster development in labor-intensive areas [15] . Countries that encourage innovation through patents appear to see tangible economic benefits in this sector. The findings support policies aimed at stimulating R&D and innovation within the sector of environmental goods and services. Investments in innovation are not just good for the environment but also stimulate the economy. The strong correlation provides a justification for both investment in research and development by public and private sectors related to environmental technologies. It shows that such investments can have a direct and quantifiable economic impact. Innovations play a crucial role in increasing the economic performance within the sector of environmental goods and services in the EU. The correlation demonstrated suggests that policies to encourage more research and development and to support intellectual property protection in the environmental sector could be highly beneficial. This perspective is particularly relevant for EU countries seeking to strengthen their economic growth while meeting environmental sustainability objectives.

4. CONCLUSIONS

The systematic investigation into SDG 9, concentrating on "Industry, Innovation, and Infrastructure," offers a comprehensive understanding of its pivotal role in driving sustainable development across the globe, particularly within the context of the European Union. Through meticulous analysis of empirical data spanning over two decades, this study underscores the instrumental impact of SDG 9 on economic growth, environmental sustainability, and social inclusion. At the core of SDG 9 is the imperative to bolster industrialization as a cornerstone for economic prosperity. The data reveal a positive trajectory in the global SDG Index Score, which, coupled with a specific focus on SDG 9, reflects significant advancements in industrial capacities across diverse economies. This upward trend is not merely indicative of increased industrial activity but also highlights the role of innovation and infrastructural developments in fostering economic resilience and diversification. The regression analyses illustrate a strong and positive correlation between the efforts directed towards innovation and infrastructure and the resultant economic outputs measured through the SDG Index. Innovation stands out as a crucial driver of sustainable industrialization. The analysis of patent applications and the corresponding R&D expenditures across EU countries points to a robust linkage between innovative activities and economic outcomes within the sector of environmental goods and services. The relationship, quantified through regression models, highlights that increases in patent filings are directly associated with enhancements in gross value added in this sector, underscoring the economic impact of innovation.

The findings suggest that fostering a culture of innovation not only aids in addressing immediate economic challenges but also equips economies with the tools to tackle long-term environmental and societal issues. This is particularly evident in the development of clean technologies and the implementation of advanced industrial processes that reduce environmental footprints while promoting economic efficiency. The European Union's experience serves as a testament to the transformative power of integrated and strategic approaches to achieving SDG 9, offering valuable lessons for other regions and countries striving towards sustainable development.

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