How research and development spending shapes societal welfare and sustainability metrics in Europe

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Abstract

This research delves into the intricate relationship between Research and Development expenditure and key societal indicators within European Union nations. Through this research we aim to elucidate the overarching relationship between the research and development investment and societal wellbeing, transcending borders and regions. Furthermore, we aim to assess the universal patterns between innovation funding and digital inclusivity, represented by the internet access rates. Another objective of this research is to determine the potential European impact of research and development allocations on sustainable practices, using the recycling rate of municipal waste and circular material use rate as key indicators. Nevertheless, we aim to contribute to the global dialogue on optimizing research and development spending for multifaceted societal and environmental advancements. Previous studies have illustrated the importance of research and development expenditure as a significant factor influencing a nation's growth, technological innovation and societal well-being. Within the European context, research has consistently shown the intricate dynamics between innovation spending and societal indicators. However, few have delved deep into the multi-dimensional outcomes of such expenditures, particularly in areas like poverty internet access and sustainable practices. Drawing upon prior studies highlight the significance of the Research and Development expenditure to national growth and societal well-being, this investigation employs a quantitative approach, sourcing data from official EU databases. Utilizing SPSS for statistical analysis, preliminary results reveal a positive correlation between the expenditure on research and development and internet access, as well as sustainable practices. The findings offer profound implications for both academia and practitioners, suggesting that investments on research and development shape diverse societal and environmental outcomes. Unique in its comprehensive exploration of the multifaceted impacts of research and development spending, this research bridges economic, societal and environmental paradigms, thereby enriching the existing academic discourse and aiding in the formulation of holistic developmental strategies within the European Union.

Keywords: sustainable practices, innovation, economic development, quantitative research.

1. Introduction

The development landscape is undergoing a significant paradigm shift in this era of extraordinary global challenges, moving towards a future where sustainable practices and societal well-being occupy center stage. The primary function of research and development spending, a fulcrum that drives innovation and directs economic advancement, is at the forefront of this revolutionary journey. Investigating in research and development not only supports technological progress but also establishes the foundation for all-encompassing answers to the complex problems that characterize our day. Europe stands out as a testing ground for understanding the complex indications between research and development spending, societal welfare and sustainability metrics as countries around the world struggle with the urgent problems of environmental degradation, social inequity and the narrowly balanced pursuit of economic growth and sustainability. The area is a global leader in the

search for a more peaceful cohabitation between human endeavors and the earth we live on because to its dedication to promoting a culture of inquiry and advancement.

This paper delves into the complex mechanisms at work, revealing the significant influence of research and development expenditures on the precarious balance between sustainability and societal well-being. Research and development have a profound impact on European nations that extends beyond the confines of labs and academic institutions. It shapes legislation, propels economic growth, and shapes the quality of life for individuals in a variety of places. We explore the strategic choices that are taken in research and development and look at how they affect social inclusion, environmental conservation, and the general well-being of European countries. We aim to shed light on how Europe. As a change agent, navigates the challenges of the contemporary world by closely examining the environment where innovation meets societal needs. This will provide insightful analysis into the changing narrative of global development during a time when sustainability and well-being are of utmost importance.

Research and development spending plays a crucial role in improving enterprise competitiveness by promoting innovation, technology transfer, and business process optimization [1]. Research and development investments can provide a source of competitive advantage in a highly competitive economy [2]. Research and development is particularly important in the automotive manufacturing industry, as it influences manufacturing safety behavior and ensures the production of safer cars [3]. Furthermore, research and development can address economic stagnation and environmental risks by creating new jobs, transforming energy production and consumption, and reducing reliance on fossil fuels [4]. In the context of manufacturing, plantation, and mining companies, research and development investment has a positive and significant correlation with eco-efficiency and firm value, highlighting its importance in improving these aspects [5].

Overall, research and development is essential for enhancing competitiveness, safety, environmental sustainability, and economic growth in various industries.

While the global context is undoubtedly crucial, this research focuses on Europe, a region renowned for its commitment to progressive policies, technological advancements, and sustainable practices. Europe's unique socio-economic landscape provides an ideal canvas for examining the intricate interplay between research and development spending and key metrics, we aim to uncover nuanced insights that can contribute to the broader discourse on sustainable development.

Studying Europe is essential for understanding the dynamics between research and development collaborations in different regions. The article by von Proff et al. examines the collaboration intensity between regions in Europe and the United States, focusing on spatial, technological, and cultural distance as factors influencing collaboration activities [6]. The study uses a panel spatial interaction modeling perspective and reveals differences in collaborative knowledge creation and the spatial range of knowledge diffusion between Europe and the United States [7]. Additionally, the articles by Bhattacharya and Erdel highlight the prevalent use of hybrid warfare as a covert strategic tool in Europe,

specifically in the case of Russian aggression towards its neighboring states [8]. Understanding these patterns of hybrid warfare is crucial for informing foreign policy decisions in the region. Therefore, studying Europe provides valuable insights into both research and development collaborations and geopolitical dynamics.

1.1. Societal welfare and sustainability metrics in Europe

In the literature studied, several connections between the variables analyzed have been found. The central focus of our literature research was to find connections, if possible, between the research and development investments and other variables related to sustainability and innovation such as "people at risk of poverty or social exclusion", "recycling rate of municipal waste", "circular material use rate" and "level of internet access- households".

Gross domestic expenditure on research and development has a significant relationship with the risk of poverty or social exclusion, as literature suggests. As research and development spending is often considered a key driver of economic growth, innovation and technological progress, higher levels of gross domestic expenditure on research and development as a percentage of Gross Domestic Product are associated with higher economic growth and Gross Domestic Product per capita [9]. This suggests that investing in research and development can contribute to reducing poverty and social exclusion.

Additionally, it is highlighted the importance of income in determining the risk of poverty. In the European Union (EU), individuals earning no more than 60% of the national median income are considered at risk of poverty [10]. Therefore, increasing the spending on research and development and promoting economic growth can potentially lead to higher incomes and reduce the risk of poverty or social exclusion.

Gross domestic expenditure on research and development has a significant and direct impact on the recycling rate of municipal waste [11]. Business expenditure on research and development, private investments, and the gross domestic product expenditures on research and development also have a direct and significant impact on recycling rate of municipal waste [12]. On the other hand, environmental taxes have a significant and inverse impact on recycling rate of municipal waste [13]. The relationship between economic growth and waste generation is also important in understanding the recycling rate of municipal waste. Previous studies have shown a bidirectional causality between waste generation and economic growth in EU regions [14]. Additionally, research and development intensity is considered an important determinant of environmental quality, and the regional level plays a crucial role in waste management policies [15]. These findings suggest that increasing research and development expenditure and implementing economic tools and eco-innovation policies are necessary to promote recycling and reduce waste generation.

Gross domestic expenditure on research and development has a positive correlation with scientific rankings of countries [16]. This suggests that an increase in research and development budgets can lead to an improvement in scientific rankings. However, there is no direct mention of the relationship between gross domestic expenditure on research and development and circular material use rate in the studied literature. The literature primarily

focuses on the relationship between economic development and material use, rather than specifically addressing the relationship between research and development expenditure and circular material use rate.

2. Research methodology

This research is centered around understanding the multifaceted effects of R&D expenditure on critical societal and environmental indicators. While the study draws extensively from data within the European Union, its broader objectives aim to shed light on universal patterns and implications, making it relevant to a global audience. The primary areas of focus include:

Societal Well-being: One of the primary dimensions of the study is to ascertain how R&D investment correlates with the overall well-being of society. This is captured through indicators such as the risk of poverty and societal exclusion, which serve as proxies for broader societal health.

- Digital Inclusivity: The research seeks to understand how innovation spending might influence digital penetration and inclusivity, represented predominantly by internet access rates. As the digital divide remains a concern globally, the findings in this dimension can have wide-reaching implications.
- Sustainable Practices: With sustainability at the forefront of global concerns, this study delves into how R&D allocations potentially affect sustainable practices. By focusing on the recycling rate of municipal waste and the circular material use rate, the research provides insights into the environmental stewardship influenced by innovation funding.

However, while the research aims for universality in its implications, it is essential to recognize the primary reliance on European Union data. As such, some specificities and nuances may be more reflective of the European context, even as broader patterns emerge.

O1. To elucidate the overarching relationship between research and development investment and societal wellbeing, transcending borders and regions.

O2. To assess the universal patterns between innovation funding and digital inclusivity, represented by internet access rates.

O3. To determine the potential global impact of research and development allocations on sustainable practices, uning the recycling rate of municipal waste and circular material use rate as key indicators.

O4. To contribute to the global dialogue on optimizing research and development spending for multifaceted societal and environmental advancements.

The analysis of the data was performed using SPSS software and the relationship between variables were investigated first through correlation and further tested through regression analysis.

3. Research findings

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In the light of the literature analyzed, the following variables (Table 1) were selected for the analysis: Gross Domestic expenditure on Research and Development, People at risk of poverty or social exclusion, Recycling rate of municipal waste, Circular material use rate and Level of internet access- households. All the data was collected from the Eurostat database, the data retrieved being for the year 2021, the newest data available online.

Table 1. The variables used for the statistical analysis

Variable	Notation	Variable type	Measuring unit
Country	Country	String	-
Gross domestic expenditure on research and development (R&D)	RD	Numerical	%
People at risk of poverty or social exclusion	PRP	Numerical	%
Recycling rate of municipal waste	RRMW	Numerical	%
Circular material use rate	CMUR	Numerical	%
Level of internet access – households	LIA	Numerical	%

Source: Authors' own representation

The descriptive statistics (Table 2) provide insight into the distribution and characteristics of the analyzed variables. R&D exhibits a mean of 1.78, indicating a moderate level of investment across the sampled countries. The slight positive skewness (0.478) suggests that some countries have higher than average R&D expenditures, such as Belgium, Sweden, Austria, and Germany with rates over 3% of GDP. The mean value of PRP is 20.4, having a positively skewed distribution (0.83), that indicates that only a few countries, such as Czechia, Slovenia, Finland, and Slovakia, have lower than average poverty rates, contributing to the rightward tail in the distribution.

Table 2. Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Variance	Skewness	Std. Error	Kurtosis	Std. Error
RD	25	.47	3.43	1.7898	.92972	.864	.478	.464	-.986	.902
PRP	25	10.70	34.50	20.4120	5.52881	30.568	.831	.464	.864	.902
RRMW	25	11.30	67.80	41.7800	15.25251	232.639	-.363	.464	-.396	.902
CMUR	25	1.40	33.80	9.8520	7.35986	54.168	1.609	.464	3.442	.902
LIA	25	83.53	99.18	91.8908	3.81874	14.583	-.098	.464	-.042	.902

Source: Authors' own representation in SPSS

The RRMW analysis presents a negatively skewed distribution (-0.363) that implies that most countries have higher recycling rates, with fewer samples with lower rates, contributing to a leftward tail in the distribution. The positively skewed distribution of CMUR (1.609) indicates that there are fewer entities with lower rates of circular material use, contributing to a rightward tail in the distribution. The higher kurtosis (3.442) suggests that the distribution has heavier tails than a normal distribution, indicating potentially extreme values. Lastly, LIA has a high mean of 91.8 and a normal distribution, as indicated by skewness (-0.098) and kurtosis (-0.042), values close to zero, suggesting a consistent and widespread level of internet access across the sampled entities.

To further investigate the relationship between variables, we performed a correlation analysis (Table 3).

The correlation matrix provides a comprehensive view of the relationships between key variables. Notably, Gross Domestic Expenditure on Research and Development (RD) exhibits significant correlations with various indicators, shedding light on potential linkages between research investment and societal outcomes.

Table 3. Correlation matrix

Correlations		RD	PRP	RRMW	CMUR	LIA
RD	Pearson Correlation	1	-.515**	.616**	.371*	.432*
	Sig. (1-tailed)		.004	.001	.034	.016
	N	25	25	25	25	25
PRP	Pearson Correlation	-.515**	1	-.414*	-.253	-.408*
	Sig. (1-tailed)	.004		.020	.111	.021
	N	25	25	25	25	25
RRMW	Pearson Correlation	.616**	-.414*	1	.457*	.437*
	Sig. (1-tailed)	.001	.020		.011	.014
	N	25	25	25	25	25
CMUR	Pearson Correlation	.371*	-.253	.457*	1	.330
	Sig. (1-tailed)	.034	.111	.011		.054
	N	25	25	25	25	25
LIA	Pearson Correlation	.432*	-.408*	.437*	.330	1
	Sig. (1-tailed)	.016	.021	.014	.054	
	N	25	25	25	25	25

**. Correlation is significant at the 0.01 level (1-tailed).
*. Correlation is significant at the 0.05 level (1-tailed).

Source: Authors' own representation in SPSS

Firstly, a negative correlation between RD and People at Risk of Poverty or Social Exclusion (PRP) suggests that regions or countries with higher RD investment tend to have lower levels of poverty or social exclusion. This underscores the potential socio-economic benefits associated with increased research spending. Additionally, RD demonstrates positive correlations with positive environmental indicators—specifically, a higher Recycling Rate of Municipal Waste (RRMW) and Circular Material Use Rate (CMUR). This implies that regions with greater research investment are likely to demonstrate more sustainable waste management practices and circular material use. Conversely, PRP shows negative correlations with environmental indicators. A higher prevalence of people at risk of poverty or social exclusion is associated with lower recycling rates and, interestingly, a lower Level of Internet Access in Households (LIA). This latter association may highlight potential digital divides in regions facing higher socio-economic challenges.

The intricate interplay between these variables underscores the multifaceted impacts of research spending on societal well-being, encompassing economic, environmental, and social dimensions. As with any correlation analysis, these associations do not imply causation, but they do provide valuable insights for policymakers and researchers to explore further and potentially inform strategies aimed at fostering inclusive and sustainable development.

Based on these arguments, the following hypotheses emerge:

- **H1**: Investments in R&D have a negative influence on the percentage of *People at risk of poverty or social exclusion* (PRP).
- **H2**: Investments in R&D have a positive influence on the *Recycling rate of municipal waste* (RRMW).
- **H3**: Investments in R&D have a positive influence on the *Level of Internet Access in Households* (LIA).

These hypotheses are further tested using regression analysis, the influences with statistical significance at p < 0.05 level being presented next.

A first regression analysis (Table 4) assessed the variation of R&D expenditures in relation to the rate of poverty. The results of the regression analysis performed to test the effects of R&D independent variable on the dependent variable PRP indicated a statistically significant prediction model (F=8.92, p <0.05), with 26,5% of PRP variability (R Square = 0.265) explained by the negative effect of R&D (β = -3.061, t = -2.880, p<0.05). Thus, the regression model indicates that higher investments in research and development, as represented by Gross Domestic Expenditure on R&D, are associated with a statistically significant reduction in the prevalence of individuals at risk of poverty or social exclusion, supporting H1.

Table 4. Results of regression analysis (dependent variable PRP)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.515[a]	.265	.233	4.841988

a. Predictors: (Constant), RD

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	194.395	1	194.395	8.292	.008[b]
	Residual	539.231	23	23.445		
	Total	733.626	24			

a. Dependent Variable: PRP
b. Predictors: (Constant), RD

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	25.891	2.135		12.127	.000
	RD	-3.061	1.063	-.515	-2.880	.008

a. Dependent Variable: PRP

Source: Authors' own representation in SPSS

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A second regression analysis was used to assess the influences exerted by Gross Domestic Expenditure on R&D on *Recycling rate of municipal waste* (RRMW). The analysis results detailed in Table 4 revealed a statistically significant prediction model (F = 14.051, p< 0.05), explaining 37,9% of RRMW variability (R Square = 0.379) through the high positive effect of R&D (β = 10.103; t = 3.748; p = 0.001, significant at $p < 0.05$). Therefore, H2 is supported by the empirical evidence.

Table 5. Results of regression analysis (dependent variable RRMW)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.616[a]	.379	.352	12.275691

a. Predictors: (Constant), RD

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2117.410	1	2117.410	14.051	.001[b]
	Residual	3465.930	23	150.693		
	Total	5583.340	24			

a. Dependent Variable: RRMW

b. Predictors: (Constant), RD

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	23.697	5.413		4.378	.000
	RD	10.103	2.695	.616	3.748	.001

a. Dependent Variable: RRMW

Source: Authors' own representation in SPSS

Table 6 presents the statistical outputs of the regression analysis between Gross Domestic Expenditure on Research and Development (RD) and Level of Internet Access in Households (LIA). The regression model is statistically significant, explaining 18,6% of LIA variation (R Square = 0.186) and predicting the increase in households' access to internet at a statistically significant level (F = 5.265, p = 0.031). Moreover, the regression path coefficient β and its statistical significance (t statistics and p value) detailed in Table indicate a significant effect for the independent variable R&D (β = 1.773, t = 2.295, p = 0.031).

Overall, R&D has significant contributions to the development of various societal and environmental indicators as follows: it exerts the lowest positive influence on the Level of internet access (LIA) and the highest positive influence on the *Recycling rate of municipal waste*, as well as a strong negative influence on *People at risk of poverty or social exclusion*. Thus, all three hypotheses are supported by the data.

Table 6. Results of regression analysis (dependent variable LIA)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.432[a]	.186	.151	3.518836

a. Predictors: (Constant), RD

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	65.196	1	65.196	5.265	.031[b]
	Residual	284.791	23	12.382		
	Total	349.987	24			

a. Dependent Variable: LIA
b. Predictors: (Constant), RD

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	88.718	1.552		57.179	.000
	RD	1.773	.773	.432	2.295	.031

a. Dependent Variable: LIA

Source: Authors' own representation in SPSS

4. Conclusions

In conclusion, the statistical analysis conducted through SPSS reveals insights into the relationship between research and development spending and societal welfare and sustainability metrics in Europe. Firstly, it is evident that research and development plays a pivotal role in shaping the recycling practices of municipal waste. The statistically significant and highest influence on the Recycling Rate of Municipal Waste highlights the instrumental role of innovation in waste management strategies. This emphasizes the importance of continued investment in Research and Development to foster sustainable practices that. Contribute to environmental preservation and resource conservation. Surprisingly, the analysis indicated notably lower positive influence of Research and Development on the Level of Internet Access (LIA). This intriguing finding suggests that while technological advancements and connectivity are crucial for societal progress, Research and Development spending may not be the sole determinant of widespread internet access. This calls for a nuanced approach in policymaking recognizing that additional factors beyond Research and Development may be influencing internet accessibility.

However, the most noteworthy revelation pertains to Research and Development's strong negative influence on the metric of People at Risk of Poverty or Social Exclusion. This counterintuitive outcome warrants further exploration and underscores the complexity of

societal dynamics. While Research and Development is traditionally associated with progress and prosperity, this finding prompts a critical examination of potential unintended consequences, signaling the need for inclusive and socially responsible innovation strategies.

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