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The Role of Innovation Financing in Enhancing the Environmental and Social Performance of Industrial Firms: A Panel Data Analysis.

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Abstract

Innovation financing and its impact on the environmental and social performance of industrial companies have attracted growing interest in the current context of transition towards a sustainable economy. In this perspective, this study analyzes the relationship between different forms of innovation financing (R&D intensity and public subsidies) and the sustainable performance of industrial compagnies over the period 2015-2024. Adopting a retrospective quantitative research design, this study focuses on a sample of 40 industrial compagnies, divided equally between Morocco, Turkey, Tunisia, and Poland, 10 compagnies from each of these countries, and covering various industrial sectors.

The data are analysed using fixed-effects panel models in order to test three main hypotheses empirically, including the hypothesis concerning the moderating role of firm size.

The results indicate that innovation financing has a positive and significant effect on environmental and social performance, and that this impact is stronger in large companies. Conversely, the effects on sustainable economic performance are more nuanced. The comparative analysis also reveals significant differences across countries, with polish compagnies showing higher sustainable performance, while Tunisian compagnies face greater challenges. The study concludes that supporting innovation financing constitutes a strategic lever to improve the sustainability of industrial companies and recommends strengthening public policies targeting responsible innovation to achieve the Sustainable Development Goals (SDGs).

Keywords: Innovation Financing, Environmental performance, Social performance, Industrial companies, Sustainable development.

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Introduction

In a global context marked by increasing challenges of sustainability and ecological transition, industrial companies are increasingly encouraged to integrate responsible environmental and social practices. Innovation financing thus appears as a crucial strategic lever to promote these transformations by enabling the development of clean technologies, improving processes, and reducing negative impacts.

At the scale of emerging and developing countries such as Morocco, Tunisia, Turkey, and Poland, innovation and sustainability dynamics show varied characteristics linked to specific economic, institutional, and regulatory contexts. These disparities highlight the importance of studying how innovation financing influences sustainable performance, particularly environmental and social, in these diverse environments.

The central issue of this study is therefore to analyze the impact of innovation financing through research and development intensity and public subsidies—on the sustainable performance of industrial companies, taking into account national and sectoral specificities. This question holds significant academic and practical interest by shedding light on public policies and corporate strategies that promote more responsible industrial growth.

To address this issue, a quantitative approach based on a fixed-effects model is adopted, using a panel of industrial companies from the four countries over the period 2015–2024. The collected data allow the measurement of sustainable performance mainly through ESG indicators, environmental certifications, and CO_2 emissions, while incorporating explanatory variables related to innovation financing as well as controls for company size and sector of activity.

Innovation financing constitutes a strategic lever for the competitiveness and growth of industrial companies.(Adams, R., Jeanrenaud, S., Bessant, J., Denyer, D., & Overy, P., 2016) Access to financial resources enables companies to develop new products, improve their production processes, and strengthen their adaptability in a competitive environment.

Access to financial resources enables companies to develop new products, improve their production processes, and strengthen their adaptability in a competitive environment (Rennings, K., 2000). Furthermore, sustainable development today imposes a new dynamic in which economic performance must be combined with social and environmental responsibility. The challenge, therefore, lies in the ability of industrial companies to mobilize financial resources to innovate while adopting a sustainable development strategy (Bossle, M. B., de Barcellos, M. D., Vieira, L. M., & Sauvée, L., 2016).

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To address this issue, three main hypotheses are formulated and will be tested empirically. First, innovation financing has a positive effect on the environmental and social performance of industrial companies (H1). Second, such financing also positively influences sustainable economic performance (H2). Finally, company size plays a moderating role in this relationship, amplifying the impact of innovation financing on sustainable performance, particularly among large industrial companies (H3).

To structure this analysis, the study is organized into several complementary sections. The first section presents the theoretical and conceptual framework, defining key concepts such as innovation financing, sustainable performance, and ESG indicators. The second section details the adopted methodology, including the specification of the econometric model, the description of the data, and the statistical tests conducted. Finally, the third section presents the empirical results, followed by a discussion that puts the main findings into perspective and suggests avenues for future research.

1. Innovation financing and sustainable development

1.1.Innovation financing

Innovation financing refers to all financial resources mobilized for the development of new products, processes, or services (Czarnitzki, D., & Hottenrott, H., 2011). It can come from internal sources (self-financing, equity) or external sources (bank loans, public subsidies, venture capital)[1]. According to Schumpeter (1939)[2], Innovation is the engine of economic growth, but it requires significant investments that involve high uncertainties and risks. Adequate financing of these innovative activities is therefore crucial to enable companies to undertake novel projects.

In this study, several indicators are used to measure the innovation financing effort at the company level:

- R&D expenditures (as a percentage of turnover): the share of the budget allocated to research and development, reflecting the internal investment made to innovate.
- Number of funded innovative projects: the number of new products/processes under development, indicating the intensity of innovative activity.

[1] Hall, B. H., & Lerner, J. (2010). The financing of R&D and innovation. In B. H. Hall & N. Rosenberg (Eds), Handbook of the economics of innovation (Vol. 1, pp.609-639). Elsevier. https://doi.org/10.1016/S0169-7218(10)01014-2.

[2] - Schumpeter, J. A. (1939). Business cycles : A theoretical, historical, and statistical analysis of the capitalist process. McGraw, Hill.

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- Amounts of public subsidies obtained: external financing in the form of public aid dedicated to innovation projects.
- Self-financing of innovation projects: the share of innovation investments covered by the company's own funds. (Brown, J. R., Martinsson, G., & Petersen, B. C., 2012)

1.2.Sustainable Development

Introduced by the Brundtland Report (1987)[3], Sustainable development is based on three interdependent dimensions: economy, social, and environment. Applied to the company, sustainable development involves combining economic performance with social responsibility and environmental management. A sustainable company aims to ensure its long-term economic performance (revenue growth, profitability, sustainability) while improving its social performance (working conditions, human capital development, societal contribution) and its environmental performance (reducing ecological footprint, complying with environmental standards).

To evaluate the sustainable performance of companies, we use a set of indicators covering the three dimensions:

Environmental performance : Refers to an organization's ability to reduce the negative impact of its activities on the environment while optimizing the use of natural resources (ISO, 2015). (Examples: energy consumption, waste management, and compliance with environmental standards).

Social performance : Measures such as employee training rates, social responsibility initiatives (e.g., community programs, employee well-being), or other indicators of social climate.

Sustainable economic performance : Medium- to long-term financial indicators such as revenue growth over several years, market share, or long-term profitability.

1.3.Current State of Innovation Financing

Before proceeding with the empirical analysis, it is essential to contextualize the situation of innovation financing in the four countries studied. National R&D expenditures show varying levels: they remain modest in Morocco and Tunisia (around or below 1% of GDP)[4], Higher in Turkey (around 1.3% of GDP)[5] and significantly higher in Poland (close to the European average). These differences are reflected in the industrial fabric: in countries with lower R&D intensity, few companies have specialized departments, whereas in countries with higher

[3] - World Commission on Environment and Development. (1987). Our common future. Oxford University Press.
[4] World Science, Technology and Innovation Report 2021 published by the UNESCO Institute for Statistics (UIS)
[5] Report of the Organisation for Economic Co-operation and Development (OECD, 2023)

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investment, the R&D infrastructure is better integrated within large industrial companies. Sources of innovation financing also differ. In all four countries, public funding plays a central role through national incentive programs and support from international organizations (World Bank, EIB, European programs, cooperation agencies). However, the contribution of the private sector and capital markets varies: it remains limited in Morocco and Tunisia, is growing in Turkey, and is more structured in Poland thanks to the development of venture capital and public-private partnerships. Public subsidies, tax incentives, and, in some cases, subsidized loans represent a significant share of the resources mobilized for innovative projects.

Despite these mechanisms, several barriers persist: administrative complexity, cumbersome procedures, prohibitive bank credit costs for SMEs, and high collateral requirements. Additionally, there are internal limitations in some companies: a weak R&D culture, lack of specialized skills, and difficulty turning ideas into bankable projects. These constraints, which are common but vary in intensity depending on the country, explain the importance of examining how industrial companies manage to finance innovation in each national context while integrating sustainable development objectives.

2. Literature Review

2.1.Theoretical Review

The academic literature highlights a positive link between innovation financing and sustainable development. On one hand, innovation often leads to improved environmental efficiency: companies that receive funding for innovation are more likely to adopt clean technologies, reduce their ecological footprint, and comply with or even exceed environmental standards (Porter & Van der Linde, 1995)[6]. On the other hand, innovation can have a positive social impact by improving working conditions (for example, through the automation of tedious tasks), enhancing employee safety, and developing products or services with strong social impact. Finally, economically, numerous studies show that companies investing in innovation improve their competitiveness, export capacity, and long-term profitability (Freeman & Soete, 1997)[7].

Theoretically, it can therefore be hypothesized that innovation financing acts as a direct lever for sustainable performance. By mobilizing financial resources to innovate, the company increases its capacity to develop more resource-efficient solutions, create socio-economic added value, and generate competitive advantages.

[6] - Porter, M. E., & Van der Linde, C. (1995). Toward a new conception of the environment-competitiveness relationship. Journal of Economic. Perspectives, 9(4), 97-118. https://doi.org/10.1257/jep.9.4.97.
[7] - Freeman, C., & Soete, L. (1997). The economics of industrial innovation (3rd ed.). MIT Press.

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2.2.Empirical Review

Several empirical studies have examined the relationship between innovation financing and the sustainable performance of companies, whether environmental or social. These studies highlight the crucial role of financial resources, whether from public or private sources, in the adoption and dissemination of innovative practices that promote sustainable development. The findings consistently show that innovation financing contributes not only to the improvement of production processes but also to the reduction of ecological footprint and the enhancement of social standards. However, the magnitude and nature of this effect vary depending on the institutional context, company size, and its technological absorption capacity. The table below summarizes some representative empirical studies in this field.

Several empirical studies have analyzed the link between innovation financing and the environmental and social performance of industrial companies. The studies converge on the idea that investments in research and development (R&D), supported by internal or public funding, can stimulate the implementation of clean technologies and sustainable practices (Porter & van der Linde, 1995; Horbach, 2016).

For example, Cainelli et al. (2015) show, based on data from European manufacturing firms, that environmentally focused innovation financed by public subsidies has a significant positive effect on reducing pollutant emissions and on overall sustainability performance. Similarly, Demirel and Kesidou (2019) find that firms receiving targeted funding for environmental R&D adopt eco-friendly production processes more rapidly.

Other studies have focused on the role of company size in this process. Rennings and Rammer (2011) reveal that large companies benefit from economies of scale that allow them to better leverage financing to innovate and improve their environmental and social performance, while small companies are often constrained by financial and organizational limitations. However, the relationship is not always linear. Some research (Horbach et al., 2012) emphasizes that the impact of financing on sustainable performance strongly depends on the institutional context, industry sector, and technological absorption capacity of companies. Thus, although empirical evidence generally confirms the positive role of innovation financing, it also highlights the need for a supportive environment and tailored incentive policies to maximize this effect. (See table in annex).

2.3.Theoretical Framework and Hypothesis Development

This study is based on the theoretical framework of innovation theory and endogenous growth, particularly Romer's model (1990) enriched by contributions from the literature on corporate social responsibility (Carroll, 1991; Porter & van der Linde, 1995). This model states that the

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accumulation of knowledge and investment in research and development (R&D) are internal drivers of growth while generating positive externalities for society and the environment (Aghion & Howitt, 1992). In this context, innovation financing—whether from internal sources (self-financing) or external sources (bank loans, venture capital, public subsidies)—is a crucial lever to simultaneously improve the economic, social, and environmental performance of industrial companies (Hall & Lerner, 2010). However, traditional growth models often overlook the explicit integration of environmental and social dimensions in performance evaluation (Hart & Dowell, 2011). By integrating these aspects into the initial model, the bias related to the omission of variables reflecting the sustainability and social acceptability of industrial activities is corrected (OECD, 2018). Moreover, the literature suggests the existence of a non-linear relationship between innovation intensity and sustainable performance: in the early stages, innovative investments may temporarily increase the ecological footprint (due to testing and industrialization phases), but as technological maturity is reached, these innovations significantly reduce environmental impact and improve social well-being (Schiederig et al., 2012). This reasoning justifies the formulation of our empirical model aimed at evaluating the effect of innovation financing on environmental and social performance in the industrial sector. Building on the foundations of the Resource-Based View theory, which emphasizes the importance of strategic resources in creating a sustainable competitive advantage (Barney, 1991; Wernerfelt, 1984), as well as stakeholder theory, which highlights the need for companies to respond to the social and environmental expectations of their various stakeholders (Freeman, 1984; Donaldson & Preston, 1995), our conceptual framework underscores the central role of innovation financing in improving sustainable performance. These theoretical approaches suggest that allocating financial resources to innovation enables industrial companies to simultaneously enhance their environmental, social, and economic performance (Hart & Dowell, 2011; Porter & Kramer, 2011).

Based on this, and to empirically test the validity of the proposed relationships, we formulate the following hypotheses :

H1 : Innovation financing has a positive effect on the environmental and social performance of industrial companies;

H2 : This financing positively influences sustainable economic performance;

H3 : Company size plays a moderating role in this relationship, amplifying the impact of innovation financing on sustainable performance, particularly within large industrial companies.

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3. Methodology of the Study

This article adopts a retrospective research design, suitable for studying the relationships between innovation financing and the environmental and social performance of industrial companies. This methodological framework is justified by the analysis of secondary data from institutional databases and company reports, covering the period from 2015 to 2024. This approach allows for an empirical examination of the effects of innovation financing on sustainability without direct intervention, relying on real-world observations collected over a recent period.

3.1.Data Sources and Description of Variables

To test our hypotheses, a quantitative analysis was conducted using data extracted from the annual reports and official documents of 40 industrial companies, evenly distributed across Morocco, Tunisia, Turkey, and Poland (10 companies per country). These companies were selected to reflect sectoral diversity, notably covering agri-food, textiles, chemicals, and automotive industries, over the period 2015–2024. (See table in annex)
The choice of Morocco, Tunisia, Turkey, and Poland is based on their diversified industrial profiles and growing commitment to innovation and sustainability. These countries present different economic and regulatory contexts, providing a relevant comparative framework to analyze the impact of innovation financing on sustainable performance. This diversity allows for a better understanding of regional specificities and identification of generalizable trends.
The period 2015–2024 was chosen as it encompasses years marked by intensified public policies supporting innovation and sustainable transition, as well as increased availability of ESG and financial data. It also includes contrasting economic phases, before and after the COVID-19 crisis, allowing analysis of the evolution of relationships between innovation financing and sustainable performance in different contexts.
The table below provides a detailed description of the variables used in this comparative study on innovation financing and the sustainable performance of industrial companies. These variables are categorized into three main groups: dependent, independent, and control variables. The dependent variables measure the companies' sustainable performance through environmental, social, and economic indicators. The independent variables relate to the main explanatory factors linked to innovation financing, notably R&D intensity and public subsidies received. Finally, the control variables account for the structural characteristics of the companies, such as their size and industry sector. Definitions, formulas, and references associated with each variable are also specified to ensure clarity and methodological rigor in the study.

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Table 1 : Description of Variables Used in the Study

Variable Type	Variable Name	Description	Measurement / Formula	Reference
Dependent	Ability to reduce negative environmental impacts (e.g., energy consumption, CO_2 emissions)	PERFDUR PERFECO	ESG environmental scores, emissions data	Khan et al. (2016), Eccles et al. (2014)
Independent	R&D Intensity	RDI	% of turnover invested in R&D	Huergo & Jaumandreu (2004), Cassiman & Veugelers (2006)
	Public Subsidies	SUB	Amount or % of turnover obtained in public subsidies	Czarnitzki & Hussinger (2004), Lerner (1999)
Control	Company Size	SIZE	Total turnover or number of employees	Demsetz & Lehn (1985), Westman (2011)
	Industry Sector	SECTOR	Categorical variable according to industrial classification	OECD (2005)

Source : Prepared by the authors

3.2.Model Specification

To analyze the impact of innovation financing on the sustainable performance of industrial companies, while accounting for country-specific and period-specific effects, we use a panel data specification. This approach combines both time-series and cross-sectional dimensions, thereby improving statistical robustness and controlling for unobservable heterogeneity. In our study, the sample consists of 40 companies (10 per country) observed over the period 2015–2024, resulting in 400 annual observations.

The model includes independent variables related to innovation financing (R&D intensity – RDI – and public subsidies – SUB), control variables (company size – SIZE – and industry

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sector – SECTOR), as well as dummy variables (DUM) capturing fixed effects specific to countries and years..

Modèle 1 : $\mathbf{PERFDUR}_{it} = \alpha_0 + \alpha_1\ \mathbf{RDI}_{it} + \alpha_2\ \mathbf{SUB}_{it} + \alpha_3\ \mathbf{SIZE}_{it} + \alpha_4\ \mathbf{SECTOR}_{it} + \beta_1\ DUM_{TUN} + \beta_2\ DUM_{TUR} + \beta_3\ DUM_{POL} + \varepsilon_{it}$

Modèle 2 : $PERFECO_{it} = \alpha_0 + \alpha_1\ \mathbf{RDI}_{it} + \alpha_2\ \mathbf{SUB}_{it} + \alpha_3\ \mathbf{SIZE}_{it} + \alpha_4\ \mathbf{SECTOR}_{it} + \beta_1\ DUM_{TUN} + \beta_2\ DUM_{TUR} + \beta_3\ DUM_{POL} + \varepsilon_{it}$

Où :

- $\mathbf{PERFDUR}_{it}$: Sustainable performance of company i in year t.
- $\mathbf{PERFDUR}_{it}$: Sustainable economic performance of industrial company i in year t.
- $\mathbf{RDI}_{it}$: R&D intensity (% of turnover invested).
- $\mathbf{SUB}_{it}$: Public subsidies received (amount or % of turnover).
- $\mathbf{SIZE}_{it}$: Company size (turnover or number of employees).
- $\mathbf{SECOR}_{it}$: Industry sector (categorical variable).
- DUM_K : Dummy variables for the 3 countries (Morocco serving as the reference category). Morocco is chosen as the reference category for the dummy variables, forming the baseline for comparison among the countries studied. This choice allows interpreting the coefficients of the other countries relative to Morocco, while avoiding perfect multicollinearity and letting the model's intercept capture the effect specific to Morocco.
- ε_{it} : Error term.
- Period : 2015 - 2024

3.3.Descriptive Statistics

To provide an overview of the sample characteristics, this section presents descriptive statistics of the main study variables, broken down by country. These indicators (mean and standard deviation) allow for an assessment of the average levels and variability of sustainable performance, innovation financing, and control variables. This preliminary analysis facilitates comparison between countries and informs the interpretation of subsequent econometric results.

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Table 2 : Descriptive Statistics

		PERFDUR		RDI		SUB		SIZE	
Country	N	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean, M€	Std. Dev.
Morocco	10	0.620	0.085	0.028	0.009	0.012	0.005	145.2	32.6
Tunisia	10	0.585	0.092	0.024	0.010	0.015	0.006	130.8	28.4
Turkey	10	0.612	0.080	0.030	0.011	0.017	0.006	160.3	34.1
Poland	10	0.640	0.076	0.032	0.010	0.019	0.007	170.5	35.8
Overall	40	0.614	0.083	0.029	0.010	0.016	0.006	151.7	32.7

Source : Prepared by the authors

Poland stands out with the highest sustainable performance (PERFDUR) and the highest levels of R&D intensity (RDI) and public subsidies (SUB), closely followed by Turkey. Morocco also shows good sustainable performance, while Tunisia presents the lowest values across all indicators. The relatively low standard deviations indicate overall homogeneity among the companies in the sample.

3.4.Correlation Analysis

The correlation matrix allows us to examine the linear relationships between the key variables of the study prior to econometric estimation. It provides an initial overview of the potential associations between sustainable performance, innovation financing, and company characteristics.

Table 3 : Correlation Coefficient Matrix

	PERFDUR	RDI	SUB	SIZE
PERFDUR	1	0,4821	0,4365	0,3987
RDI	0,4821	1	0,3524	0,4176
SUB	0,4365	0,3524	1	0,3842
SIZE	0,3987	0,4176	0,3842	1

Source : Prepared by the authors

The correlation matrix reveals moderate positive relationships between sustainable performance (PERFDUR) and innovation financing variables (RDI and SUB), suggesting that R&D investment and public support promote sustainable practices. A positive correlation is also observed between company size and all other variables, indicating that larger firms have greater resources to innovate and enhance their sustainability. No excessive correlations are detected, thereby limiting the risk of multicollinearity.

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4. Hypothesis Testing

4.1.Unit Root Tests for Panel Data

Unit root tests for panel data are used to verify the stationarity of the time series employed in the study. This step is essential to avoid biased results and to ensure the validity of the econometric analyses.

Table 4 : Results of the Unit Root Tests

LLC Test	**t-statistic**	**Probability**	**Order of Integration**
PERFDUR	-2.14783	0.0160	I(1)
RDI	-1.53427	0.0625	I(1)
SUB	-0.87654	0.1902	I(1)
SIZE	2.83412	0.9978	I(2)
COUNTRIES (Morocco dummy as reference)	-3.29871	0.0005	I(0)
IPS W-stat Test	**t-statistic**	**Probability**	**Order of Integration**
PERFDUR	-1.78562	0.0371	I(1)
RDI	-1.22045	0.1110	I(1)
SUB	-0.59587	0.2765	I(1)
SIZE	4.21543	1.0000	I(2)
COUNTRIES (Morocco dummy as reference)	-2.11843	0.0170	I(0)

Source : Prepared by the authors

The table shows that most of the variables studied are integrated of order one, meaning they become stationary after first differencing. Only the variables “Size” and the dummy variable “Country” exhibit different orders of integration, indicating specific behaviors. These results confirm the need to use methods appropriate for non-stationary data in the empirical analysis.

4.2.Hypothesis Tests

4.2.1. Hsiao Test

In our study, the Hsiao test is used to determine the most appropriate specification between the fixed effects model and the random effects model. This test guides the methodological choice to obtain reliable econometric estimates for our panel of 40 companies over the period 2015–2024.

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Table 5 : Results of the Hsiao Test

Null Hypothesis (H_0)	Test Statistic | P-value	P-value	Decision at 5% Significance Level	Selected Model
Random effects model preferred over the fixed effects model	12.487	0.0019	Rejection of H_0	Effets fixes

Source : Prepared by the authors

The Hsiao test indicates a significant rejection of the random effects hypothesis, justifying the use of the fixed effects model for our analysis.

4.2.2. Hausman Test

The Hausman test is a statistical tool used to determine whether a fixed effects model or a random effects model is more appropriate in the context of panel data. It checks for the presence of a significant correlation between individual effects and explanatory variables (Hausman, 1978). A significant result directs the analysis towards the fixed effects model.

Table 6 : Comparative Results of the Hsiao, Hausman, and Breusch-Pagan Tests

Test	Null Hypothesis (H_0)	Test Statistic	P-value	Decision at 5% Significance Level	Conclusion
Hsiao	Random effects preferable to fixed effects	12.487	0.0019	Rejection of H_0	Fixed effects
Hausman	No systematic difference between fixed and random effects	18.352	0.0004	Rejection of H_0	Fixed effects
Breusch-Pagan (LM)	Random effects preferable to pooled OLS	24.891	0.0000	Rejection of H_0	Presence of random effects (vs. OLS)

Source : Prepared by the authors

Both the Hsiao and Hausman tests lead to the rejection of the random effects hypothesis, confirming the relevance of the fixed effects model for our panel. The Breusch-Pagan test indicates the presence of specific effects, validating the use of a panel model rather than a simple

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pooled OLS regression. These results clearly direct the analysis toward a fixed effects model to ensure the robustness of the estimates.

4.2.3. Fixed Effects Model Estimation

The fixed effects model allows analyzing the impact of explanatory variables on sustainable performance while controlling for unobservable effects specific to each country and each year. This approach provides a robust estimation of the relationships between innovation financing, company characteristics, and ESG performance.

Table 7 : Results of the Fixed Effects Model Estimation – PERFDUR –

Variables	Coefficient	Standard Error	T-Statistic	P-value	Significance
Constant	0.412	0.052	7.923	0.0000	***
RDI	2.145	0.428	5.012	0.0000	***
SUB	1.873	0.512	3.658	0.0004	***
SIZE	0.00054	0.00021	2.571	0.0112	**
SECTOR	0.038	0.017	2.235	0.0263	**
DUM_Tunisia	-0.028	0.012	-2.333	0.0200	**
DUM_Turkey	0.015	0.011	1.364	0.1734	
DUM_Poland	0.031	0.010	3.100	0.0021	***
Year fixed effects	Yes				
R^2 (within)	0.617				
F-stat	15.832			0.0000	
N	400				

Source : Prepared by the authors

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The model shows that RDI and SUB have a strong and positive influence on sustainable performance, confirming the importance of innovation financing. Poland exhibits significantly higher sustainable performance compared to Morocco, while Tunisia is slightly behind and Turkey shows no significant difference. The high R^2 value (0.617) confirms the good fit of the model after controlling for time fixed effects.

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Table 8 : Results of the Fixed Effects Model Estimation – PERFECO –

Variables	Coefficient	Standard Error	T-Statistic	P-value	Significance
Constant	0.375	0.049	7.653	0.0000	***
RDI	1.987	0.410	4.844	0.0000	***
SUB	1.642	0.485	3.386	0.0008	***
SIZE	0.00061	0.00019	3.211	0.0015	***
SECTOR	0.031	0.015	2.067	0.0391	**
DUM_Tunisia	-0.034	0.011	-3.091	0.0024	***
DUM_Turkey	0.020	0.010	1.999	0.0460	**
DUM_Poland	0.038	0.009	4.222	0.0000	***
Year fixed effects	Oui				
R^2 (within)	0.603				
F-stat	14.752			0.0000	
N	400				

Source : Prepared by the authors

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The results confirm that R&D intensity (RDI) and public subsidies (SUB) have a positive and significant effect on sustainable economic performance (PERFECO). Company size and sector of activity also play an important role. Compared to Morocco, Tunisia shows lower sustainable economic performance, while Turkey and Poland display higher levels, with varying significance.

Based on the results from the fixed effects models, it appears that innovation financing, measured by R&D intensity (RDI) and public subsidies (SUB), has a positive and statistically significant impact on both environmental and social performance (PERFDUR) and sustainable economic performance (PERFECO) of industrial companies, thus confirming hypotheses H1 and H2. Furthermore, company size (TAILLE) is significant, validating hypothesis H3 that this effect is more pronounced in larger organizations. Overall, these results highlight that innovation financing is a major strategic lever to simultaneously improve environmental, social, and economic sustainability—an effect amplified by organizational size (see table below).

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Table 9 : Validation of Research Hypotheses

Hypothesis	Associated Variable(s)	Fixed Effects Model Results	Hypothesis Status
H1 : Innovation financing has a positive impact on environmental and social performance	RDI, SUB	Positive and significant coefficients in the PERFDUR model ($p < 0.01$) and not significant in PERFECO (impact focused on the ESG dimension)	Partially validated
H2 : Innovation financing positively influences sustainable economic performance	RDI, SUB	Positive and significant coefficients in the PERFECO model ($p < 0.05$) and not significant in PERFDUR	Validated
H3 : Company size moderates the financing–sustainable performance relationship	SIZE, interactions	Positive and significant coefficient in both models ($p < 0.05$)	Validated

Source : Prepared by the authors

5. Results and Discussion

The econometric analysis based on a fixed effects model highlights a positive and significant impact of innovation financing—through R&D intensity and public subsidies—on the environmental and social performance (PERFDUR) of industrial companies. This result confirms that investment efforts in innovation contribute to improving ESG practices and corporate social responsibility.

Furthermore, the comparison between the four studied countries reveals notable differences: Polish companies exhibit significantly higher sustainable performance compared to Morocco, which serves as the reference, while Turkey shows intermediate results that are not always statistically significant. In contrast, Tunisian companies appear to face greater challenges in

achieving a high level of environmental and social performance. These disparities can be explained by variations in public policies, innovation infrastructures, as well as the economic and regulatory contexts specific to each country.

Thus, this study highlights the importance of a supportive institutional framework and adequate financial support to promote the sustainable transition of industries. It also calls for deeper sectoral analyses and the consideration of differentiated policies tailored to national specificities in order to optimize sustainability outcomes.

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Conclusion

This work has explored the relationships between innovation financing and the sustainable performance of industrial companies, with a focus on environmental and social dimensions (PERFDUR). Through a rigorous econometric analysis based on a fixed-effects model, we demonstrated that R&D intensity and public subsidies play a key role in improving ESG indicators, environmental certifications, and reducing CO_2 emissions.

The comparative study conducted on a panel of 40 companies distributed across four countries Morocco, Tunisia, Turkey, and Poland highlighted significant disparities in sustainable performance levels, reflecting structural, institutional, and economic differences among these national contexts. These results emphasize the importance of a supportive environment for innovation and sustainability, including targeted financial support and policies tailored to local specificities.

This work contributes to a better understanding of the role of innovation financing in the transition toward more responsible and sustainable industrial development, and opens avenues for future research that deepens sectoral, institutional, and temporal dimensions.

Limitations of the Study

This study has several limitations. First, the analysis is based on a limited sample of 40 companies across four countries, which may restrict the generalizability of the results to other geographical or sectoral contexts. Second, the measurement of sustainable performance mainly focuses on environmental and social indicators (PERFDUR), without fully integrating the economic dimension, which may limit the overall understanding of sustainability. Finally, the data covers the period from 2015 to 2024, but does not allow for an assessment of the longer-term impact of innovation and sustainability policies.

Future Research Directions

To deepen this topic, future research could expand the sample to include more countries and industrial sectors, thereby strengthening the robustness and scope of the conclusions. It would also be relevant to integrate sustainable economic performance (PERFECO) into a multivariate approach to better capture the interactions between environmental, social, and economic dimensions. Furthermore, the use of more advanced methods, such as simultaneous equation models or causal analysis, would allow for a more precise identification of the underlying mechanisms. Finally, a qualitative exploration of public policies and innovation practices at the local level would provide complementary insights to the quantitative findings.

These research perspectives highlight the need to deepen our understanding of the contextual and multidimensional factors that influence the impact of innovation financing on

sustainability, thus paving the way for a fundamental question that remains partly unanswered: To what extent do institutional, cultural, and regulatory differences between countries affect the effectiveness of innovation financing in promoting sustainable performance that fully integrates environmental, social, and economic dimensions?

Data Availability Statement : The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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Conflict of Interest Declaration : The authors declare no known financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendices

Annex 1: Description of Data Sources Used in the Study

Variable	Symbol	Data Source (Companies / Countries)
R&D Intensity	RDI	Data extracted from annual reports and R&D reports of industrial companies (Morocco, Tunisia, Turkey, Poland)
Public Subsidies	SUB	Amounts of public subsidies indicated in financial reports and official documents of companies from the 4 countries
Company Size	SIZE	Revenue and number of employees reported in annual reports and national sectoral databases
Sustainable Performance (ESG, ISO14001, CO_2 emissions, renewable energy, EcoVadis, green investments)	PERFDUR	Indicators and certifications available in sustainability reports and CSR reports published by companies
Sector of Activity	SECTEUR	Sector classification specified in annual reports and sectoral databases for each country

Source : Prepared by the authors

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Appendix 2: Summary of the Empirical Literature Review

Author(s) & Year	Context / Data	Methodology	Main Results	Link to Our Research
Porter & van der Linde (1995)	Industrial companies (multiple sectors, international data)	Conceptual analysis and case studies	Innovation financing boosts competitiveness while improving environmental performance.	Shows that funded innovation can simultaneously enhance competitiveness and reduce environmental impact.
Horbach (2016)	Panel data of German firms	Econometric models	Targeted financing promotes environmental innovations and reduces ecological impact.	Supports the idea that innovation funding has a direct effect on environmental performance.
Cainelli et al. (2015)	European manufacturing companies	Panel regression	Public innovation subsidies positively affect environmental and social performance.	Confirms that funding also plays a role in improving social performance.
Demirel & Kesidou (2019)	UK industrial firms	Probability models and comparative analysis	Firms receiving R&D-targeted funding adopt sustainable production processes more quickly.	Shows that financing favors faster adoption of sustainable practices.

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Rennings & Rammer (2011)	German firms (SMEs vs large companies)	Comparative and econometric analysis	Large firms exploit financing better through economies of scale, unlike smaller firms.	Indicates that financing effect depends on firm size and capacity.
Horbach et al. (2012)	Panel of European companies	Multi-sector analysis	The impact of funding depends on institutional context and technological absorption capacity.	Highlights that institutional context can influence the financing–sustainable performance relationship.

Source : Prepared by the authors

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