The role of technological intensity, cluster membership, and internationalisation for greater green innovation: The case of the Valencian Community

El papel de la intensidad tecnológica, la pertenencia a clúster y la internacionalización para una mayor innovación verde: El caso de la Comunidad Valenciana

Jeanneth Marcela Valdivieso-Uvidia *

Business Administration Department, Universitat Politècnica de València, (Campus de Alcoy). Alcoy, Spain.

marvaluv@upv.edu.es • https://orcid.org/0009-0001-8519-2552

Manuel Expósito-Langa

Business Administration Department, Universitat Politècnica de València (Campus de Alcoy). Alcoy, Spain.

maexlan@doe.upv.es • https://orcid.org/0000-0001-7707-7354

José Antonio Belso-Martínez

Department of Economic and Financial Studies Miguel Hernández University. Elche, Spain.

jbelso@umh.es • https://orcid.org/0000-0003-2985-7481

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* Corresponding Author
Jeanneth Marcela Valdivieso-Uvidia

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Abstract: This study analyses differences in the development of green innovation among manufacturing firms in the Valencian Community, Spain. Based on factors related to technological intensity, territorial integration and internationalisation, this research assesses whether firms follow different patterns when it comes to engage in product- and process-related green innovation. The findings indicate that the industry's technological intensity is a catalyst for green innovation development, with technologically advanced sectors demonstrating a higher intensity in the adoption of green products and production processes. Moreover, territorial anchoring, based on industrial cluster membership, enhances green product innovation, while the demands for international markets are positively associated with both green product and process innovation. The findings have important implications for regional economic development, highlighting the need for developing business and institutional specific support strategies for low technology-intensive sectors, strengthening industrial clusters as collaborative ecosystems, and supporting firms' internationalisation for greater corporate sustainability.

Keywords: : Green innovation; technology intensity; internationalisation; industrial cluster.

Resumen: Este estudio analiza diferencias en el desarrollo de la innovación verde en las empresas manufactureras de la región de la Comunidad Valenciana en España. Basándose en distintos factores como son la intensidad tecnológica sectorial, la integración territorial y la internacionalización, se evalúa si las empresas adoptan patrones de comportamiento distintos diferenciando entre innovación verde en producto y en proceso. Los resultados revelan que la intensidad tecnológica sectorial permite diferenciar entre los niveles de desarrollo de la innovación verde, siendo los sectores más tecnológicos donde el desarrollo de productos y procesos verdes tiene mayor intensidad. Por otra parte, el anclaje territorial, a partir de la pertenencia a clústeres industriales, facilita un contexto donde las empresas intensifican más

su innovación verde en producto, mientras que las exigencias de los mercados internacionales se asocian positivamente tanto con la innovación verde en producto como en proceso. Estos hallazgos tienen importantes implicaciones para el desarrollo económico regional, destacando la necesidad de establecer estrategias específicas de apoyo, tanto empresariales como institucionales, a los sectores de baja intensidad tecnológica, el fortalecimiento de los clústeres como espacios de colaboración y el papel de la internacionalización en la promoción de la sostenibilidad empresarial.

Palabras clave: Innovación verde; intensidad tecnológica; internacionalización; clúster; sectores industriales.

1. Introduction

In the current context of growing global environmental and economic concerns, the ability to innovate within the framework of sustainability has become a cornerstone for the success and survival of companies (Neumann, 2021; Schrank & Kijkasiwat, 2024). From an economic perspective, the relevance of this topic lies in the fact that companies face a complex competitive landscape, simultaneously determined by pressures to adapt to stricter environmental regulations, to meet the demands of environmentally conscious consumers, and to compete in highly dynamic global markets. Initiatives such as the European Union's Agenda 2030 and the United Nations Sustainable Development Goals represent unprecedented stimuli for the adoption of sustainable economic development models (Benavides-Sánchez et al., 2022; Vallet-Bellmunt et al., 2022).

Green innovation is defined as the incorporation of environmentally friendly criteria in the development of products and/or processes, seeking to minimize the ecological impact of business activity (Anjum et al., 2024; Chen, 2008; Chen et al., 2006; Díez-Vial et al., 2023; Martínez-Falcó et al., 2024). Moreover, its adoption serves a dual purpose: mitigating environmental impacts and promoting compliance with international standards that enhance the global competitiveness of companies (Dechezleprêtre & Sato, 2017). This type of innovation not only responds to the premises of environmental sustainability; it also offers strategic opportunities for company growth and differentiation in increasingly competitive markets (Becker, 2023; Expósito-Langa et al., 2024; Horbach, 2008; Porter & Van Der Linde, 1995). Recently, a wide range of studies have confirmed the role of green innovation in companies as a tool for generating competitiveness in a socioeconomic context marked by growing global environmental concerns (Afeltra et al., 2023; Belso et al., 2024; Kraus et al., 2018; Maldonado-Guzmán & Pinzón-Castro, 2022). Thus, a rapid adaptation to the sustainability demands of consumers and organizations of various kinds (Cleff & Rennings, 1999; Neumann, 2021; Schrank & Kijkasiwat, 2024), allows access to a set of new business possibilities rooted in this trend towards global sustainability (Andersson et al., 2022).

Under these premises, certain business factors contribute to the development of green innovation in companies. Firstly, technological intensity participates, not only driving innovation (Afeltra et al., 2023) but also redefining the paradigms of competitiveness and business growth (Ambec et al., 2013; Díez-Vial et al., 2023; Zameer et al., 2022; Zhao et al., 2021). Despite the academic consensus on the impact of technological endowment on business performance (Apak & Atay, 2015; Bommer & Jalajas, 2004), the bias towards technological innovation means that its effect in other domains has been neglected (Hatzichronoglou, 1997; Peiró-Signes et al., 2011; Zawislak et al., 2018). Thus, in recent years, there has been a commitment to a more holistic understanding of innovation that also integrates social and environmental dimensions (Belso-Martinez et al., 2020; González-Masip et al., 2019).

Secondly, belonging to industrial clusters and territorial networks (Boix & Galletto, 2006; Ter Wal & Boschma, 2011), is closely linked to innovative activity in general (Expósito-Langa et al., 2015) and environmental innovation (Belso et al., 2024). Thanks to their location in a cluster, companies benefit from spillover effects and acquire specific resources (e.g.

knowledge) that allow them to adapt to technological changes and to the demands of the changing socioeconomic context (Becker, 2023; Belso-Martínez & Díez-Vial, 2018). Proof of this is the reinforcement exerted by the territory's own resources on the internal capabilities of companies when innovating in the environmental sphere (Weng et al., 2015).

Finally, the international presence of companies is another determining factor in the development of green innovation. Internationalisation not only expands market opportunities (Belso-Martinez et al., 2020; Weng et al., 2015) but also forces companies to improve their efficiency and sustainability to meet international standards (Husted et al., 2016; Rodríguez-Pose et al., 2021), thus contributing to more sustainable growth and differentiation in highly competitive markets (Denicolai et al., 2021).

Accordingly, in the context of the current debate on how firms can achieve sustainable growth trajectories through green innovation (Attig et al., 2016; Belso et al., 2024; Benavides-Sánchez et al., 2022; Chiarvesio et al., 2015), we have chosen these variables, justified by their theoretical and empirical relevance in the field of sustainability and green innovation, and as drivers of the transition towards sustainability in manufacturing companies with high environmental impact (Maldonado-Guzmán, 2024; Pereira et al., 2024), also supported by the previous work of others (Expósito-Langa et al., 2024; Valdivieso-Uvidia et al., 2024). In short, given this theoretical framework, the following research question arises: Do firms differ in terms of green innovation development taking into account the differentiating factors of technological intensity, cluster membership and internationalisation?

The choice of the Valencian Community (Spain) as the object of study is relevant because its economy accounts for around 10% of Spain's GDP. In turn, it is an industrially diversified region, consisting of both more traditional sectors and other highly technological ones, with great international activity and an ecosystem that favours entrepreneurship. Moreover, after adverse situations such as the economic crisis of 2008 or the COVID, companies have shown resilience and have managed to recover the pace of the region's economy. Therefore, further study of this specific context will allow conclusions to be drawn that could be extrapolated to other economies with similar regions, whether in Europe, America or Asia, where there is deep-rooted industrial activity, considering the cultural and regulatory specificities of each area.

The results obtained from the statistical methods applied identify differences in the factors indicated and the development of green innovation, providing relevant empirical evidence on a complex and multifaceted phenomenon. Beyond the academic contribution, our contribution has implications at the level of business management or the design of extremely valuable public actions. The article is divided as follows: firstly, it offers the conceptual foundations that give rise to the proposal of the research questions. Secondly, the scenario studied is described and the research variables are proposed. Following this, the empirical results obtained are shown and discussed, and finally, some implications and conclusions are offered.

2. Theorical framework

This study is framed within the growing attention that green innovation has received in academic and business contexts due to its potential to address global environmental challenges. Green innovation, as defined by Chen (2008), refers to the adoption of practices and technologies aimed at reducing environmental impacts, either through products or processes. Sectoral technological intensity is understood as the level of investment in research and development activities relative to the sector's value added (Hatzichronoglou, 1997; OECD, 2017). In addition, a cluster understood as geographic concentrations of interconnected firms within a specific industry, facilitate innovation by promoting cooperation and enabling access to shared territorial resources, thereby enhancing regional innovation. (Boix & Galletto, 2006). Finally, internationalisation refers to the participation of firms in global markets through activities such as exports and imports, which require the adoption of sustainable practices due to international regulations and demands (Denicolai et al., 2021).

2.1. Technology Intensity and Green Innovation

Sectoral technology intensity refers to the level of concentration of technology and R&D investment in a specific sector (Abdal et al., 2016; Botey-Fullat et al., 2018). According to the OECD (2017), its role as an indicator in measuring the proportion of investment in research and development activities (R&D&I) in relation to the total sales of a given sector has made it possible to classify industries according to the amount of technology incorporated in their processes and products at a global level. Thus, sectoral technological intensity helps to understand how technologically advanced a sector is and to identify where technological innovation effort is concentrated in the economy as a whole (Hatzichronoglou, 1997; Lampón & Rivo-López, 2022; Zawislak et al., 2018).

There is evidence in the academic literature on how firms in specific sectors tend to show a greater predisposition towards innovation, recently highlighting environmental innovation (Parrilli et al., 2023; Peiró-Signes et al., 2011; Valdivieso-Uvidia et al., 2024), both at the product and process level (Chen et al., 2006; Díez-Vial et al., 2023; Oduro et al., 2022). For instance, companies operating in high-tech-intensive sectors, such as the automotive industry, are better positioned to develop green innovations in both products and processes due to their technological capabilities and investments in R&D (Maldonado-Guzmán, 2024)the inability of employees to innovate knowledge and skills, the high price of green technologies, and the lack of environmental awareness in organizations are the biggest threats to the environmental and sustainable development. In this context, manufacturing companies in emerging markets should not only focus on achieving a higher level of business sustainability in economic and financial terms, but also pay attention to financial and green innovation, because they are important ways to achieve a green transformation of businesses, to improve sustainability, and to reduce carbon dioxide emissions. This study provides data on the adoption and repercussions of these activities on the sustainability of manufacturing companies in Mexico. The proposed research model was validated by applying partial least squares structural equation modeling (PLS-SEM. However, the debate on how the technological environment of different sectors may influence these two types of green innovation remains unresolved (Abdal et al., 2016; Peiró-Signes et al., 2011; Zhu, 2024).

While there may be some agreement on the direct relationship between technology intensity and green innovation, there is no agreement on the uniformity of the same in terms of its typology. Some studies point to significant variation between the development of new products (Dangelico, 2016) and the improvement of existing processes or the implementation of new processes (Stucki, 2019). To advance the understanding of how sectoral characteristics influence green innovation trajectories in industrial firms, we propose the following research question:

Q1: Are there differences in the role of sectoral technology intensity between green product and process innovation in industrial firms?

2.2. Cluster and green innovation

Clusters, defined as geographical concentrations of interconnected companies in a particular industry (Boix & Galletto, 2006; Boschma & Fornahl, 2011; Ter Wal & Boschma, 2011; Zhang & Yi, 2024), foster innovation through cooperation and access to shared resources attached to the territory contributing to regional innovation (Balland et al., 2016; Hervas-Oliver & Albors-Garrigos, 2009). Green innovation is no exception in relation to the positive effect exerted by practices such as knowledge sharing and joint learning in an atmosphere of trust, typical of cooperation in clusters, thus favouring the competitiveness of its members (Belso et al., 2024; Mercado-Caruso et al., 2020).

The concentration of resources, talent and expertise in a geographically determined space strengthens the firm's ability to adapt to technological and market changes quickly (Expósito-Langa et al., 2015). The complexity involved in green innovation that ranges from eco-design to advanced production models that provide significant economic and socio-

environmental benefits (Becker, 2023; Chen et al., 2006; Weng et al., 2015; Zhu, 2024), makes clusters ideal spaces for this innovation to germinate.

Thus, the introduction of new practices aimed to green innovation not only reflects an environmental commitment for the territory but also opens new market opportunities (Belso-Martínez & Díez-Vial, 2018). For example, the visibility and immediacy of green innovation at the product level, as well as changes and investments in the manufacturing process, allows for monetization in the consumer market. In order to better explore the differences, a second research question is proposed:

Q2: Are there differences in the role of cluster membership by industrial companies between green product and process innovation?

2.3. The Impact of International Activity

Due to globalization and advances in information and communication technology, companies have intensified their international presence. This growing international operation presents endless challenges and opportunities for companies (Anjum et al., 2024; Zhang et al., 2020). While reducing the dependence of these firms on local markets (Werneck-Barbosa et al., 2022), international activity involves exploring more competitive and demanding markets (Denicolai et al., 2021; Porter & Van Der Linde, 1995).

Thus, companies are forced to comply with stricter standards that require highly innovative practices compared to those they have been previously developing (Husted et al., 2016; Rodríguez-Pose et al., 2021). It is in this context where the implementation of strategies consistent with environmental regulation and emerging consumer demands becomes important, which, in turn, encourages the introduction of environmentally sustainable innovations (Belso-Martinez et al., 2020; Horbach, 2008; Weng et al., 2015). Following the comparison between locally operating versus internationalized companies we formulated our third research question:

Q3: Are there differences between internationally active industrial companies in their development of green product and process innovation?

3. Methodology

3.1. Sample and data

The Valencian Community in Spain is a region that stands out notably in the Spanish industrial landscape, its economic growth being determined by investment in key sectors such as tourism, industry, agriculture and construction (Pérez et al., 2024). According to data from the Valencian Institute of Economic Research (IVIE, 2021), the region represents 10.6% of the Spanish population, contributes 9.3% of the national Gross Domestic Product (GDP) and accounts for 8.1% of the country's total expenditure in Research and Development (R&D).

In the industrial context, the Valencian Community accounts for 11.4% of the national total and according to the latest report of the Observatory of Corporate Governance, Strategy and Competitiveness (GECE, 2023), small and medium-sized companies in the Valencian Community have a high level of competitiveness and added value generation. This region is characterised by a diverse productive structure, with a high specialisation in low- and medium-technology intensity sectors, reflecting both the challenges and opportunities of the transition to toward sustainable practices. At the same time,

certain high-tech-intensity sectors have a level of competitiveness above the national average, positioning them as potential leaders in the adoption of green innovations.

The selection of manufacturing companies in this region is justified by their significant economic and employment relevance. According to the structural business statistics of the Generalitat Valenciana (2020) 25.683 companies were registered in the industrial sector, the majority of which belonged to the manufacturing industry. This sector generated a turnover of €55.006 billion, representing 85.5% of the total industrial sector, and employed an annual average of 249.770 people, representing 89.8% of industrial employment in the region. These figures highlight the predominant contribution of the manufacturing industry to the economic and social development of the Valencian Community.

These characteristics position the Valencian Community as an ideal setting for analysing how factors such as technological intensity, territorial integration, and internationalisation influence the ability of manufacturing companies to implement green innovations. It provides a representative case of the industrial dynamics faced by regional economies in Europe.

This empirical study is based on data obtained from a sample of companies representing various productive sectors in the region (Table 1). The universe is composed based on the basis of data provided by the Generalitat Valenciana (2020), which recorded 22.361 companies in the industrial sector belonging to the manufacturing industry in the Valencian Community. This sector, characterised by its remarkable heterogeneity, included a wide variety of economic activities classified according to the divisions established in the National Classification of Economic Activities (CNAE-09).

To ensure the representativeness of the sample, a simple random sampling method was used, with a maximum sampling error margin of ±7% and a confidence level of 95%. The data collection instrument, a questionnaire primarily directed at executives or managers in charge of for research and development (R&D) areas, was developed between November 2020 and January 2021.

Before its final implementation, a pilot test was carried out with an initial sample of ten randomly selected companies. The feedback and suggestions received during this phase allowed the questionnaire to be optimised, improving its clarity and effectiveness. A rigorous data cleaning process was then carried out to remove incomplete or inconsistent responses, resulting in a validated sample of 189 companies. The diversity of companies in this study offers a unique opportunity for analysis on the challenges faced by companies in their adaptation to green innovation and sustainability policies promoted at national and European level (Díez-Vial et al., 2023).

3.2. Common method bias

Considering the possibility that our research might be affected by common method bias (CMB) due to the use of data obtained from the same instrument applied to the same individual participant in each company, we first applied Harman's single-factor test following the recommendations of Podsakoff et al. (2012), a widely used approach in research within this field (Baquero, 2024; Hayat & Qingyu, 2024; Maldonado-Guzmán & Pinzón-Castro, 2022). This procedure involves subjecting all scale items to an exploratory factor analysis (EFA) while constraining the extraction to a single factor.

To assess the suitability of the factorial analysis, we obtained a Kaiser-Meyer-Olkin (KMO) value of 0.816, indicating an acceptable adequacy of the data for factor analysis. Additionally, Bartlett's test of sphericity was statistically significant ($\chi^2 = 596.314$, $df = 28$, $p < 0.000$). Regarding the explained variance, the first extracted factor accounted for 38.819% of the total variance, which is below the 50% threshold recommended by Podsakoff et al. (2012) for considering common method variance (CMV) as a potential issue. These results suggest that CMV is unlikely to represent a significant threat to the dataset or substantially affect the relationships between the model's variables.

Table 1: Bussiness Structure of the Sample

Category: Number of Employees		
Characteristics	**Number of Companies**	**Frequency (%)**
Less than 10 employees	30	15.9
Between 11 and 49 employees	120	63.5
More than fifty employees	39	20.6
[a] Category: Annual Revenue (Millions of euros)		
Characteristics	**Number of Companies**	**Frequency (%)**
Low (less than €3 million)	91	48.1
Medium (more than €3 and less than €6 million)	43	22.8
High (€6 million or more)	55	29.1
[b] Category: Industrial Activity		
Characteristics	**Number of Companies**	**Frequency (%)**
Non-electric Machinery	13	6.9
Pharmaceutical Industry	13	6.9
Scientific Instruments	12	6.3
Office Machinery and Computer Equipment	12	6.3
Electrical Machinery	11	5.8
Chemicals	11	5.8
Food	21	11.1
Toys - Plastic	23	12.2
Textile	20	10.6
Footwear	24	12.7
Furniture	15	7.9
Paper, Advertising, and Paint	14	7.4

Note: N = 189. [a] Values corresponding to the fiscal year 2021. [b] Based on the main business activity within traditional industries.
Source: Own elaboration

3.3. Variables measurement

Green Product Innovation. This variable measures the degree of integration of environmental aspects in the design and development of products in the company (Chen, 2008; Dangelico, 2016). To measure this variable, we have used an adapted version of the metrics applied in several studies (Barforoush et al., 2021; Chen et al., 2006; Dangelico, 2016; Leonidou et al., 2015). The final scale has been adjusted to these five items, measured using a five-point Likert scale. To validate the scale, a confirmatory factor analysis was performed using SPSS, following the methodological recommendations of Coakes and Steed (2001). To reinforce construct validity, convergent validity was assessed by calculating the average variance extracted (AVE) and composite reliability (CR), according to the criteria established by Fornell and Larcker (1981). Table 2 presents the obtained results.

Green Process Innovation. The green innovation in processes variable assesses the extent to which companies implement sustainable practices in their manufacturing processes to reduce or mitigate their environmental impact (Díez-Vial et al., 2023; Wasiq et al., 2023; Yao et al., 2021; Zhang et al., 2020). It is structured around three key items, which were measured using a five-point Likert scale assessing the degree of implementation of these practices in the company. As in the case of Green Product Innovation, a confirmatory factor analysis was conducted, and convergent validity was assessed by calculating the Average Variance Extracted (AVE) and Composite Reliability (CR). Table 2 summarizes the findings of this analysis.

Sectoral Technology Intensity (STI). To operationalize this variable, the methodology proposed by the Organisation for Economic Co-operation and Development (OECD, 2017) has been adopted, based on indicators that reflect both production and technology use, including R&D expenditure in relation to value added and traditional industry output. This classification, widely recognized and used in empirical research globally, distributes industries into four categories of technological intensity: high, medium-high, medium-low and low (Abdal et al., 2016; Botey-Fullat et al., 2018; Hatzichronoglou, 1997). Considering the sample obtained, we finally classified the companies into two main categories according to their sector: low and medium-high technological intensity. Specifically, 61.9% of the companies (117 companies) belong to low-technology-intensive sectors, while 38.1% (72 companies) are in medium-high technological intensity sectors.

Cluster membership. This variable assesses the firm's membership in a sectoral territorial agglomeration. That is, if the company has the benefits of belonging to a cluster structure, such as interconnection, collaboration and access to shared resources (Balland et al., 2016; Belso-Martínez & Díez-Vial, 2018; Expósito-Langa et al., 2015; Rodríguez-Pose et al., 2021). To determine cluster membership, we used the methodology proposed by Boix and Galletto (2006), which is widely recognised in studies on territorial and economic dynamics. This methodology emphasizes the importance of territorial interactions for innovation and competitiveness, as also highlighted by Boschma and Fornahl (2011), Rodríguez-Pose et al (2021) and Expósito-Langa et al (2015).

In our approach firms were classified based on their geographical location within areas identified as industrial clusters, using key criteria such as the concentration of interrelated economic activities and the availability of shared resources. In addition, this analysis was complemented by secondary data obtained from the database SABI (Iberian Balance Sheet Analysis System), carefully validated in the context of this study to ensure its relevance to the Valencian Community. Thus, in the context of the sample analysed, the companies are divided into two categories: those that are part of a cluster and those that are not. Specifically, of the total 189 manufacturing companies in the sample, 58.2% (110 companies) belong to a cluster, while 41.8% (79 companies) do not.

Internationalisation. This variable covers the participation of companies in the global market in the roles of exporter, importer or both (Neumann, 2021). In the context of the sample, a significant proportion, 76.2% (144 companies), participate in international markets. The 52% (99 companies) are involved in combined import and export activities, while 19% (35 companies) focus exclusively on exports and 5% (10 companies) are involved exclusively in imports. On the other hand, 23.8% (45 companies) do not participate in international activities.

3.4. Analysis techniques

Non-parametric statistical techniques were used to analyse the data obtained in order to evaluate the relationships between variables. This type of methodology is of interest when the data do not meet the assumptions of normality and homogeneity of variances required by parametric tests such as ANOVA (Berlanga-Silvestre & Rubio-Hurtado, 2012). In this case, the data do not strictly meet the normality criteria, thus justifying the need to apply these techniques in order to handle the diversity of the sample data (Fagerland, 2012).

Non-parametric tests were applied for two independent samples and to analyse three nominal variables (STI, Cluster and Internationalization) and scale variables (Green Product Innovation and Green Process Innovation). To make comparisons between groups, the Mann-Whitney U-test was used to test whether the differences are significant. In addition, the chi-square statistic was used to evaluate the independence between categorical variables and to verify the association between business characteristics and their level of segregated green innovation.

Table 2: Results of Variable Measurement

Variables		Constructs	Factor Loadings	Factor Analysis
Green Innovation	Green Product Innovation	1. We use materials that optimise resources and energy	.729	Cronbach's α = .828 KMO = .788 Bartlett's Sphericity Test Chi-square = 301.222 df = 10, sig < .000 CR = 0.878 AVE = 59.96%
		2. We employ biodegradable or recyclable materials	.822	
		3. We reduce material use to minimise pollution	.724	
		4. We use sustainable packaging	.753	
		5. We develop environmentally responsible products	.811	
	Green Process Innovation	1. We implement actions to reduce waste and residues.	.782	Cronbach's α = .828 KMO = .802 Bartlett's Sphericity Test Chi-square = 335.475 df = 6, sig < .000 CR = 0.877 AVE = 70.35%
		2. We integrate measures into processes to decrease energy consumption.	.857	
		3. We optimise water use in production processes and improve raw material management.	.875	

Note: df = Degrees of Freedom. CR = Composite Reliability. AVE = Average Variance Extracted.
Source: Own elaboration.

4. Results

The results of the Mann-Whitney U Test for the variables Green Product Innovation and Green Process Innovation, taking STI as the grouping variable, are shown below in Table 3.

Table 3: Statistical Results of Comparison by STI Category

[a](STI)	[b]x^2	Z	Standard Error	Median Rank	
				Low	Medium-High
Green Product Innovation	5.198***	2.703	(364.980)	85.57	108.70
Green Process Innovation	5.045**	2.314	(360.264)	87.88	106.58

Note: N = 189, [a] Grouping Variable: Sectoral Technological Intensity (STI). [b] Mann-Whitney U Test; Significance level .01 (***); Significance level .05 (**)
Source: Own elaboration.

These results highlight that the technological intensity of a sector serves as a differentiating factor in the development of green innovation. Firms in medium-high technological intensity sectors show significantly higher levels of green innovation,

underlining the crucial role of investment in research, development, and innovation (R&D&I), and advanced technological capabilities, in driving the implementation of green innovations.

Moreover, the differences observed are more pronounced for green product innovation. This suggests that more technologically intensive sectors prioritise the development of products that better meet environmental criteria. On the other hand, while differences are also observed for green process innovation, they are less pronounced. This may be because process innovation tends to be more incremental and is influenced by specific internal practices within each company.

These findings are relevant to the first research question because they reinforce the importance of sectors with higher technological intensity in promoting green innovation. They clearly identify significant differences between groups based on their sectoral technological intensity, suggesting that this variable is associated with higher levels of green innovation.

To answer the second research question on how cluster membership may lead to differences in the ability of firms to develop green innovation, Table 4 presents the results obtained:

Table 4: Statistical Results of Comparison by Cluster Category

[a] Cluster	[b] x^2	Z	Standard Error	Median Rank	
				NO	YES
Green Product Innovation	3.606**	-1.992	(370.697)	88.29	104.35
Green Process Innovation	4.098	-0.675	(365.907)	98.13	92.75

Note: N = 189, [a] Grouping Variable: Cluster Membership. [b] Mann-Whitney U Test; Significance level .01 (***); Significance level .05 (**)
Source: Own elaboration.

These results show the differences in the behaviour of companies that belong to a cluster with respect to those that do not in terms of the development of Green Product Innovation. Firms located in industrial clusters show a higher propensity to develop green innovation products, highlighting the importance of the collaborative dynamics and the shared knowledge effects that are characteristic of clusters.

In contrast, the results reveal no significant differences in green process innovation (Chi-square = 4.098 and Z = -0.657, sig. = .500) between companies inside and outside clusters. This suggests that, while collaborative networks and geographical proximity promote the development of green products, process improvements may depend more on firm-specific internal capabilities than on external cluster dynamics. The observed superiority of clustered firms in green product innovation may be due to factors such as rapid access to market trends, the availability of shared resources and the sharing of technical and market knowledge. These findings reflect significant associations between cluster membership and green product innovation.

Finally, internationalisation was applied as a grouping variable. Table 5 shows that there is a significant difference in green innovation among internationally active companies. These results show that internationally active firms exhibit higher levels of green innovation in both products and processes, which may reflect an adaptation to the demands of global markets. Importantly, the observed differences are of a similar magnitude for both types of innovation, which may suggest that internationally active firms tend to adopt a more comprehensive green approach. However, this association does not imply a direct causal relationship but rather highlights a pattern where internationalised firms show a broader commitment to sustainability strategies.

Table 5: Statistical Results of Comparison by Internationalisation Category

[a] Internationalisation	[b] x^2	Z	Standard Error	Median Rank	
				NO	YES
Green Product Innovation	3.742*	2.097	(312.657)	79.39	99.46
Green Process Innovation	3.937*	2.206	(315.972)	79.51	99.84

Note: N = 189, [a] Grouping Variable: International Activity. [b] Mann-Whitney U Test; Significance level .01 (**); Significance level .05 (*)

Source: Own elaboration.

It is worth noting that the differences are of a similar magnitude for both products and processes, suggesting that internationalisation promotes a comprehensive green innovation strategy. Internationalised companies appear to prioritise the development of sustainable products to meet the demands of stringent markets, while at the same time optimising their processes to ensure efficiency and regulatory compliance. This conclusion reinforces the importance of internationalisation on the road to business sustainability and answers the third research question. Furthermore, although 5% of our sample consist of companies whose international activities are limited to imports, these organisations still have significant potential to contribute to green innovation. With access to global inputs and technologies, they can integrate practices that complement their sustainability strategies within their operational frameworks. This shows that even the most basic forms of internationalisation offer valuable opportunities to promote sustainable practices. This finding highlights the different mechanisms through which internationalisation is positively associated with green innovation.

5. Discussion

This study provides empirical evidence on the crucial role of technological intensity, cluster membership, and internationalisation in promoting green innovation among manufacturing firms in the Valencian Community, Spain. The findings allow for the identification of differentiated levels of green innovation adoption among the analysed groups. These results are partially consistent with previous research highlights the complexity of green innovation and its interaction with internal and external factors (Horbach, 2008; Chen et al., 2006; Díez-Vial et al., 2023).

The observed relationship between sectoral technological intensity and green innovation reflects significant differences in the level of green innovation adoption across sectors with different technological intensities. Companies in medium-high technological intensity sectors show higher levels of green innovation, both in products and processes. These findings confirm previous studies that emphasise the importance of investing in R&D and developing technological capabilities to foster green innovation (Maldonado-Guzmán, 2024; Parrilli et al., 2023; Valdivieso-Uvidia et al., 2024). According to Zhao et al (2021), high-technological industries have a greater capacity to develop green innovations due to their investments in research, development, and innovation (R&D&I), and their advanced technological capabilities.

However, it is also evident that companies in low-technology-intensive sectors exhibit lower levels of green innovation. This is consistent with studies such as that by Pham et al (2023), which show that low-technology-intensive sectors face significant barriers to adopting green innovations, including resource and capability constraints. These challenges result in lower sustainability performance compared to more advanced sectors. This pattern is also observed in other Spanish regions, such as Andalusia and Galicia, where traditional, low-intensity production structures predominate (D'Agostino & Moreno, 2019; Maudos, 2024). These findings underscore the need to design specific policies to address these barriers, facilitate access to resources, technology, and training, and promote green innovation, especially in less technologically advanced sectors.

Cluster membership is associated with significantly higher levels of green product innovation, which may be related to knowledge spillovers and collaborative dynamics that facilitate sustainability-driven innovation (Belso-Martínez & Díez-

Vial, 2018; Boix & Galletto, 2006; Expósito-Langa et al., 2015). However, as observed in this study, no significant differences were found in green process innovation. This finding may reflect that internal process improvements are more influenced by individual firm capabilities than by external factors, as suggested by Molina-Morales and Expósito-Langa (2013). It is also possible that the limited green process innovation reflects the low effectiveness of tacit knowledge transfer within the cluster, which could be due to cultural, technological, or trust barriers that hinder the efficient flow of knowledge, as shown by Han and Xu (2024). This highlights the opportunity to evaluate and design concrete strategies to strengthen the internal capabilities of firms within clusters, particularly in relation to green processes.

The results show that internationalised companies exhibit significantly higher levels of green innovation in both products and processes. This could be related to their exposure to international markets, which tend to impose stricter environmental standards and demand higher levels of sustainability. Denicolai et al (2021) argue that participation in global markets encourages the adoption of broader sustainable strategies, such as green innovation. As noted by Anjum et al (2024), the relationship between internationalisation and green innovation is neither uniform nor direct. Therefore, as in previous cases, it cannot be claimed that internationalisation directly leads to higher levels of green innovation. Instead, there is an observed association that suggest that firms operating in global markets tend to adopt broader green innovation strategies to meet environmental demands. This underlines the importance of promoting policies that facilitate the internationalisation of companies, especially in low-technology-intensive sectors, to promote their integration into sustainable value chains and access to advanced green technologies.

6. Implications, limitations and future research

6.1. Theoretical Implications

This study advances the theoretical understanding of the factors driving green innovation, particularly in the industrial context. It provides empirical evidence on the different roles of technological intensity, territorial integration through clusters, and internationalisation in promoting green innovations. This, in turn, highlights the multifaceted nature of green innovation and underscores the importance of sectoral differences, especially in regions with diverse industrial structures, such as the Valencian Community.

The findings support existing theories on how technological capabilities and collaborative environments promote eco-innovation (Belso et al., 2024; Díez-Vial et al., 2023; Horbach, 2008; Maldonado-Guzmán & Pinzón-Castro, 2022). Additionally, the study emphasizes the need for a deeper exploration of the differences between green innovation in products and processes, as well as the inclusion of importing companies within the definition of internationalisation as a more comprehensive approach. This will allow for the analysis of how these organisations, although representing only 5% of the sample, participate in the innovation dynamic by accessing international green resources, technologies, and knowledge. All of this contributes to the growing body of literature on these dynamics in a nuanced and differentiated manner.

6.2. Practical and Policy Implications

The findings of this study have significant implications for entrepreneurs, industry, and public administration in promoting green innovation. From a practical perspective, the results highlight the importance of strategic investments in research and development (R&D) and the promotion of collaboration through industrial clusters to enhance the eco-innovative potential of companies. For businesses in high-technology intensive sectors, continuous investment in green

technologies and the development of dynamic capabilities are essential to maintain competitiveness. In contrast, companies in low-technology-intensive sectors should focus on adopting existing green innovations and improving process efficiency to enhance sustainability and market visibility.

For the industry, adopting green innovations not only responds to market and consumer pressures (Anjum et al., 2024; Huang & Li, 2017), but also serves as a pathway to achieving a long-term competitive advantage (Parrilli et al., 2023; Yao et al., 2021). Managers can capitalise on consumer demand for sustainable products by developing branding and marketing strategies that emphasise their commitment to environmental sustainability. This approach can enhance both market differentiation and customer loyalty.

From a policy perspective, public administration plays a crucial role in fostering green innovation by creating a supportive environment for businesses. Policies that incentivise investment in R&D, particularly in low-technology-intensive sectors, can help bridge technology gaps and overcome barriers to entering more global markets. Additionally, programmes to support industrial clusters can encourage collaborative innovation and resource sharing, particularly in the development of sustainable products.

6.3. Limitations and Future Research

Although this study provides valuable insights into the mechanisms of green innovation, it has several limitations. First, the analysis focuses exclusively on the manufacturing sector in the Valencian Community, which limits the generalisability of the findings to other regions and economic sectors at both national and international levels. Future research could explore the dynamics of green innovation in tertiary sectors and economies with different industrial structures to better understand how the drivers of eco-innovation vary in different contexts.

Another limitation of this study is the diversity of the manufacturing sectors analysed, which cover different levels of technological intensity. The classification used, based on the OECD methodology, does not fully capture the internal diversity or the specific innovation capacity of each sector. Knowledge-intensive industries, such as pharmaceuticals, are very different from the traditional manufacturing sectors, such as furniture, textiles, or footwear, that predominate in the Valencian Community. While this heterogeneity provides a broader perspective, it may also introduce variability that affects the comparability of the results. Future research could refine this classification and focus on more homogeneous sectoral samples to draw more precise conclusions.

The inclusion of importing firms in the definition of internationalisation is a limitation. Although these firms may contribute to the development of innovative capabilities through access to external inputs and technologies, their impact on the implementation of green innovations may differ significantly from firms with a broader international profile. A more detailed analysis of the international profile of firms, distinguishing between exporting, importing and other forms of internationalization, could further enrich this study and will be considered in future research.

While the study addresses key variables such as technological intensity, clusters, and internationalisation, it does not consider other equally relevant dimensions, such as organisational culture, internal factors, or firm strategies. Including these variables in future research could significantly enrich the theoretical model and provide a more comprehensive understanding of the determinants of green innovation.

Moreover, future studies could use advanced regression analyses to assess the combined impact of these variables and explore the role of mediators and moderators, with particular attention to regional and sectoral differences. Additionally, it is crucial to delve deeper into the barriers to the adoption of green innovations. Understanding these constraints would

provide a more balanced and critical perspective on this concept, which is becoming increasingly important in the strategic organisational domain.

7. Conclusions

The results of this empirical study allow us to draw several relevant conclusions. First, this work makes a significant contribution to the theoretical understanding of the factors driving green innovation in manufacturing companies in the Valencian Community, Spain, a region characterised by a combination of sectors with different technological intensities and a strong industrial base (GECE, 2023). By analysing the differences between sectoral technological intensity, cluster membership, and internationalisation, the study provides an integrated perspective that links these factors to green innovation and, to some extent, to corporate sustainability.

These findings are in line with previous studies that highlight the link between investment in R&D, technological capabilities, and the development of green innovations (Horbach, 2008; Lampón & Rivo-López, 2022). This finding underscores the importance of designing specific support policies to overcome these constraints and promote their participation in sustainable initiatives (Barforoush et al., 2021).

Second, the results highlight the central role of industrial clusters as collaborative platforms associated with green product innovation through knowledge sharing and local network effects (Belso et al., 2024). However, as no significant associations were found between cluster membership and green process innovation, firms may need specific tools to support the optimisation of sustainable processes within these industrial networks (Han & Xu, 2024).

Third, internationalisation is positively associated with green product and process innovation. Internationalised companies are more exposed to stringent regulations and diversified demands, which encourages the adoption of green innovations in both products and processes. This finding provides empirical evidence on the link between international dynamism and sustainability-oriented business strategies, suggesting a possible positive influence (Anjum et al., 2024; Attig et al., 2016; Belso-Martínez, 2006; Expósito-Langa et al., 2024).

Finally, in addition to contributing to the theoretical advancement of green innovation this work addresses a gap in the empirical literature. Unlike studies that have prioritised the conceptualisation of green innovation and sustainability, this study offers a comparative group approach that links key factors to the specific dynamics of an industrialised region such as the Valencian Community. Moreover, the results have the potential to be extrapolated to other regions with similar industrial characteristics, providing valuable guidelines for future research.

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